THE LIFE AND WORK OF SIR HIRAM MAXIM

BY THE SAME AUTHOR

WILLIAM GILBERT OF COLCHESTER

LEADING ENGLISH SCIENTISTS

THE BIBLIOGRAPHICAL HISTORY OF ELECTRICITY AND MAGNETISM

ELECTRO-CHEMISTRY

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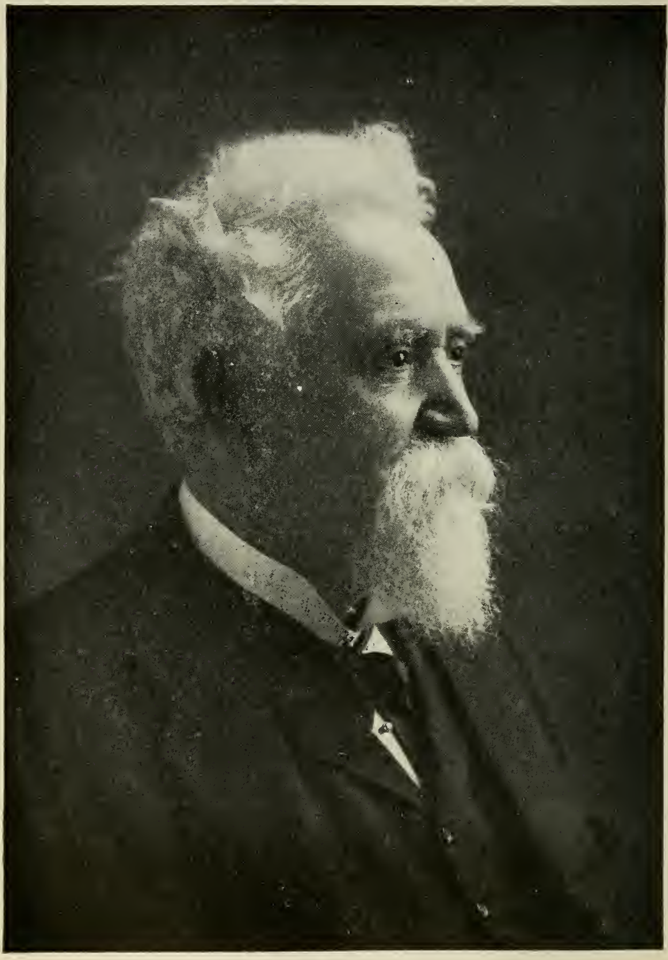

SIR HIRAM MAXIM, AT THE AGE OF SEVENTY-FOUR

THE LIFE AND WORK OF SIR HIRAM MAXIM

KNIGHT, CHEVALIER DE LA LÉGION D'HONNEUR, ETC. ETC.

BY P. FLEURY MOTTELAY

WITH AN INTRODUCTION BY THE RT. HON. LORD MOULTON K.C.B., G.B.E., F.R.S.

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FOREWORD

HIRAM STEVENS MAXIM claimed French Huguenot ancestors, who, said he, had been driven from France by the edict of Nantes and who finally settled in Plymouth County, Massachusetts, U.S.A., after having taken habitation for a while in Canterbury, Kent, England. His grandfather, born in Wareham, Massachusetts, experienced many vicissitudes before he could complete possession of a small tract of land along the shores of Androscoggin Lake, where he and his wife, Eliza Rider, long dwelt peacefully with their seven children. The youngest of these was Isaac Weston Maxim, who, after having worked in different localities and at various employments, decided to settle at Sangerville, Maine, where he married Harriet Boston Stevens, the daughter of Deacon Stevens of Abbott Upper Village. The subject of our sketch, Hiram Stevens Maxim, was born February 5th, 1840, and, with the other children, lived up to the year 1846 on the small plot of land which their father had purchased and cleared. At a later period, Hiram's parents decided to abandon farming and to engage in wood turning at French's mills, where the children could at the same time attend the village school. In a letter to his son Percy, dated March 25th, 1914, Hiram Maxim says: ". . . Of course, I should tell you all about the kind of life I lived in the town of Sangerville—a poor little bare-headed, bare-footed boy with a pair of blue drill trousers, frayed out at the bottom, open at the knees, with a patch on the bottom, running wild but very expert at catching fish. I think I was nine years old when I left Sangerville. . . ."

From French's mills they moved to the small town of Milo, where they likewise engaged in wood turning, and thence to Orneville, which place offered greater advantages, especially in the way of water power. There they became owners of a well-established grist mill, not far from the local school which all the children attended.

During 1854, when fourteen years of age, Hiram was apprenticed to one Daniel Sweat, who was a carriage maker at East Corinth. He remained in Sweat's employ until the family returned to Sangerville, where he again did journeyman's work, until an opportunity presented itself to enter the large carriage manufacturing and repair shop of Daniel Flynt, established at a place called Abbott Lower Village. With Flynt he was connected for about four years, off and on, and it was while he was thus employed that Hiram Maxim perfected his first invention. This was an automatic mouse-trap, which proved most effective in ridding the village grist mill of the swarms of mice that infested it. The invention was shortly after followed by others for an improved tricycle, for a silicate blackboard, etc. None of these inventions, however, were covered by patents.

At the age of twenty, in February 1860, Hiram went to Dexter, Maine, where he worked both as a decorative painter and wood turner, and, after following many occupations, he decided to travel throughout Canada and the Northern States, finally landing at Fitchburg, Massachusetts. There he entered the engineering works of his uncle, Levi Stevens, who shortly afterwards was given a contract to construct a number of Drake's automatic gas machines. Hiram's inventive genius almost at once improved upon the manufacture of these, and, later on, he succeeded in entering the employ of Oliver P. Drake, a philosophical instrument maker in Boston, for whom the gas machines had originally been made. It was while at Drake's, and after he had left the place, that Hiram designed several density regulators as well as an automatic sprinkler for extinguishing fires.

Hiram Maxim's next important employment was at the Novelty Iron Works and Shipbuilding Company in New York City, where he brought about further improvements in automatic gas machines, locomotive head lights, etc., upon all of which he secured patents that were duly assigned to a new American corporation called the Maxim Gas Machine Company. Another corporation was subsequently formed in London, under the name of the Maxim-Weston Company, to control all Maxim and Weston electrical appliance patents throughout Great Britain.

It was at this period that electric lighting was being much discussed in the scientific world, and Hiram was fortunate in meeting a Mr Spencer D. Schuyler who had formed the first United States Electric Lighting Company, of which he was president, and who employed Hiram as chief engineer as well as general manager. Although Hiram's experience had hitherto not been in the direction of electrical matters, the inborn inventiveness of the man soon manifested itself, and, at an early date, he applied for and obtained a patent for standardizing carbon filaments by electrically treating them in an attenuated atmosphere of hydrocarbon vapours. He engaged himself extensively in the manufacture of dynamos, arc lamps, and other electrical apparatus. He also devised a ready process for the economical production of pure phosphoric anhydride (P_2O_5) again showing that the chemistry of the day had something to learn from him, and, as the lists of patents herein will indicate, he continued making improvements in America in other directions up to the year 1881. His first trip to Europe was made in that year, in order to attend the Paris Electrical Exposition, where he received the Cross of Chevalier de la Légion d'Honneur from the President of the French Republic for his electrical exhibit. It was when in Paris on this occasion that he made the first drawings of an automatic weapon. On re-visiting London he was introduced by Mr Randolph R. Symon, Vice-President of the Mexican Central Railway, to Mr Albert Vickers, and these three gentlemen formed, in 1883-4, the Maxim Gun Company which, four years afterwards (July 20th, 1888), amalgamated with the Nordenfelt Guns and Ammunition Company and became Vickers Son & Maxim, Limited.

The subsequent most important strides in the progress of Hiram Maxim were his inventions of explosives, smokeless powders, aerial torpedoes and flying machines.

In the long list of Sir Hiram Maxim's American patents are embraced the following multifarious devices: curling hair irons; gas generators, etc.; carburetters; steam traps; meters; pumps; chandeliers; heaters; storage batteries; apparatus for demagnetizing watches; engines; governors; regulators; electric lamp fixtures; dynamos, etc.; magneto-electric machines; processes of recovering solvents, of rivetting, of stone dividing or cutting, and magnetic separators.

Among Sir Hiram Maxim's British patents may be enumerated processes for the separation of metals; for the manufacture of pipes and tubes; for extracting gold from refractory ores; for obtaining a high vacuum; for the determination of wind velocity; for vacuum cleaning; for the production of illusionary effects; apparatus for preventing the rolling of ships; for increasing the speed of ships; to secure the washing out of drains; for minor aeronautical purposes ; eyeletting and rivetting machines ; carburetters ; feed water check valves ; steam generators ; wheels for railways and tramways ; bombs for flying machines ; new advertising methods ; shafts for screw propellers ; inhaler for cure of bronchitis and kindred ailments ; motor driven velocipede and other vehicles ; oil and gas engines ; boot and shoe heel protectors ; pumps ; regulators for electric car motors ; pneumatic tyres ; electric railway conduit systems ; coffee substitutes ; also method of extinguishing fires in theatres.

Sir Hiram not only introduced a bullet-proof cuirass—as to which we would refer our readers to the files of the London *Engineer* and *Engineering* for 1894—but also numerous captive fiying machines, and an air-gun which, on trial, gave to its projectile a greater velocity than had previously been obtained by any other device of its kind. It may be added here that the blackboard before alluded to was made by coating wood with a mixture consisting mainly of fine emery, pumice and lampblack, which, after painting and drying, proved to be as good a silicate as could be desired.

Hiram Stevens Maxim always described himself as " a chronic inventor." And justly so, for his discoveries, as will be seen in the Appendix, actually exceed by far in number, and cover a much wider field, than those of any of the leading scientists of his day. He always said that he left no stone unturned in order to become expert at anything he had to do, and often spoke of the "glorious" period when all his leisure time was given to studying such books as he could procure upon the subject that happened to engage him at that moment. He was naturally possessed of a singular mastery of detail, became an indefatigable worker, and soon proved to be a many-sided man, in the true acceptation of the term, for he always evinced a ready grasp of any laboratory or other technical difficulty that presented itself in the novel fields into which he was often called upon to enter.

In the following pages his most important inventions are purposely presented in detail, as they have never before appeared in print. They are explained for the most part in his own words—just as they were dictated by him to his secretary—so that the reader may fully appreciate the peculiar individuality that always characterized his work and the infinite care that he gave to the solution of the problems—many of a most intricate nature—which came before him during his very long career.

In 1900 Maxim became a naturalized British subject, and he was knighted the following year by the late Queen Victoria, after which many distinctions were conferred upon him by different countries.

He was married, first to Jane Budden, by whom, he says in a letter dated March 27th, 1911, he had three children in ten years. His second wife was Sarah Haynes ("born in Boston") by whom he had no children. He died at Streatham, November 24th, 1916, in his seventy-seventh year, and was buried in the large cemetery at West Norwood.

Probate of his last will, which was executed July 25th, 1916, was granted to his widow and to his solicitor. He left estate valued at about £33,000. The household furniture, horses, carriages, etc., he gave to his wife, and legacies of £1000 each to Mrs Josephine Lewis and to Mrs Romaine Dennison of Mount Vernon in the State of New York. The residue of his estate was placed in trust for his wife for life, with remainder as to one-third for his grandson, Maxim Joubert, £4000 to Mrs Dennison, £4000 in trust for Josephine Lewis, and the ultimate residue for his blood relations as Lady Maxim may appoint.

Thanks are hereby extended to Lord Moulton for his sympathetic and very instructive introduction, as also to Major C. C. Colley, Mr Achille Bazire, and Mr F. W. Cowham for the assistance they have given in various ways in the preparation of this publication, also to the editors of London *Engineering* and *The Engineer* for permission to make all needed extracts from their extensive files, and to Mr Alan Cartwright for leave to use the fine portrait of Sir Hiram Maxim which appears in the frontispiece.

INTRODUCTION

SIR HIRAM MAXIM was a born inventor. He was constitutionally incapable of resting content with what he found in any department of the world of industry to which he chanced to devote his attention for the moment—it was a necessity of his nature to propose some improvement. This restless search after something new and different from that which others practised might, in the case of a man of different mental calibre, have led to a useless life frittered away in effectual attempts to better that which was being fairly handled by men with special knowledge and experience of the matter in question. But he was saved from this by the possession of three great qualities. In the first place his mind was intensely practical, so that there remained in it a complete and accurate picture of the potentialities of substances or processes with which he had had experience in his very diversified life. In the second place, he was gifted with a lightning-like rapidity in separating the essentials of a problem from the non-essentials, so that he saw clearly isolated from each other, and in their simplest form, the real forces at his command and the work which he must make them perform. And in the third place, he was gifted with a genuine and remarkable inventive faculty, by which I mean that he had the imagination which could devise wholly new grouping of the means at his command instead of mere modifications of that which he saw in use already.

That a mind so versatile and an energy so irrepressible should occasionally have led him to make so-called inventions which were trivial and of little value was inevitable. He rarely, if ever, took the trouble to ascertain the existing state of knowledge in any subject which he took in hand. His instinct was to set to work to make something that was better than what he saw—that would succeed where it failed; and anything that he thus devised he assumed was novel and that he was the first and true inventor of it. This led him to take out many useless patents, the validity of which could hardly have been sustained in a Court of Law, and the value of which was doubtful. But these do not detract from the really great value of his life's work. They only serve as indications of the bent of his strong personality, the might of which is to be judged by his achievements when he engaged himself on matters worthy of his powers.

I had frequent opportunities of seeing Sir Hiram Maxim and having long and intimate talks with him over his inventions. I always found him a most engaging personality. As eager and enthusiastic as a boy, he would pour out his accounts of the way he had made his inventions, their performances and their successes, the alternatives that he had thought of and the reasons for his choice of those which he had adopted. In so doing he made manifest an almost incredible wealth of ideas and fertility of conception till one felt that all that was needed was to keep such a mind engaged on problems worthy of it. Fortunately this was what actually happened. In several of the great movements of his time he took a large share, and in all of them he left his mark.

I first became acquainted with his work in 1881, on the occasion of the Electric Exhibition and Congress at Paris. The attention of the whole civilized world was at that time concentrated on electric lighting. That it would play a great part in public and private lighting in the future was universally expected, but the question to be decided was whether this would

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be effected by the sub-division of the arc-light or the adoption of the as yet undeveloped incandescent lamp. Three rival incandescent lamps were then known, viz., the Edison, the Swan, and the Maxim lamp. The Edison and the Swan were practically identical—the work of independent inventors but differing in no essential particular. But the Maxim lamp had been arrived at on different lines, and if it had been equally fortunate in the financial and industrial agencies into whose hands it fell it would, in my opinion, have proved a formidable rival to its competitors in those early days, and it establishes for Sir Hiram Maxim a claim to share in the invention and introduction of electric lighting, one of the great luxuries of modern civilization.

A good example of the fertility of his invention is to be found in this connection. It was essential for the success of incandescent electric lighting that the lamp filaments should possess a uniform resistance, and the methods of manufacture were then, and for some time afterwards, too imperfect to accomplish this. Accordingly, Maxim devised and patented the method of standardizing them (technically known as "flashing") by electrically heating them in a hydrocarbon atmosphere. This patent was, unfortunately, allowed to lapse; but if it had been kept in form and could have been supported it would have established for Maxim a claim to a still greater share in the merit of making electric light practicable. I am, however, not sure that in this he could have established priority of invention, for, if my memory serves me, it was held that the invention belonged to a prior patentee who had proposed it for a purpose unconnected with incandescent lamps. However this may be, it was undoubtedly a genuine invention on the part of Maxim not derived from any person, and it shows the fertility of his mind and his power of dealing with the difficulties that presented themselves in the work in which he was engaged.

Electric lighting was, however, only one of the early loves of Sir Hiram Maxim. His fame rests principally on his work in less peaceful fields of effort, and it was in connection with them that I was brought into closest contact with him and had the best of opportunities of appreciating the marvellous fertility of his mind. His first great triumph in this direction was the automatic gun. It was the complete realization in practice of a most daring conception, viz., to make the force of recoil in a gun actuate the mechanism for re-loading and firing it. The firing was thus rendered absolutely automatic and the limitations which govern the rapidity or accuracy of human action no longer affected the performance of the gun. I have seen it fire more than 600 shots per minute while maintaining accuracy of aim. This invention may fairly be said to have permanently changed the condition of modern warfare, and although the same type of mechanism as was successfully used in his first and best-known gun is not used in all its successors, yet he can claim to have foreshadowed most, if not all the methods of attaining action in guns in the patents which he took out during the early days of the development of the Maxim gun. How great have been his services in the development of modern artillery in other directions can only be known to the managers and directors of the great company with which he became identified for the rest of his life. But it is clear that he was an inspiration in all directions of its work which ranged over all forms of artillery.

It was not only in guns, however, that he showed his inventive powers. He can claim to have been one of the original inventors of nitro-glycerine powders. Here his good fortune was not so marked as in the case of the automatic gun, for his name is not generally associated with the discovery. Indeed, the credit given to him for it is greatly less than his deserts. He realized the necessity of keeping the proportion of nitro-glycerine low and adding an oil to introduce an extra amount of carbon and thus lessen the temperatures of the gases produced by the explosion. Unfortunately he chose castor oil, and worded his specification so as to lead the Courts to hold that he meant an animal or vegetable oil in contradistinction to a mineral oil, *i.e.* a hydrocarbon. But for this I think that he would have succeeded in the long litigation which he had with the Government whom he accused of infringing his patent by the use of the later forms of cordite. In judging of his merits as an inventor one must look at the substance of what he invented, and it must be admitted that he had independently arrived at what is essentially the most modern form of powder as well as the most modern form of quick-firing guns.

From these he turned to the problem of flight. Here he did not attain success. He was so early in the field that he was forced to depend entirely on the results of his own experiments, and though he obtained valuable data for those who were to follow him he never succeeded in making a machine that would fly. I remember well his taking me to see his machine which was then nearly completed. He was confident of the success of aviation though he was doubtful whether his machine would succeed. He was sorely handicapped by having to use steam owing to the fact that the internal combustion engine was so imperfectly developed; and if my memory serves me, he had not hit upon the arrangement of planes in the fore part of the machine which experience seems to have shown to be essential to success. But his grip upon the data of the problem was remarkable, and had he continued to work upon it I feel confident that he would have been one of the chief contributors to the development of the modern flying machine.

The last interview which I had with him was when he came to me as the Director of Explosives Supply to offer me his services during the war should I be in need of them. He was still the youthful and eager optimist that I had always found him. He felt as strongly as any Englishman could have done that our cause was that of civilization itself, and he was ready to volunteer to aid it. Soon afterwards I learnt of his death with deep regret. His life had been one long period of intellectual activity, marked not only by great and momentous successes but also by a wealth of practical and theoretical work which must prove of vast service to those who follow along the same paths as he trod.

MOULTON

London, *February 13th*, 1919

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THE LIFE AND WORK OF SIR HIRAM MAXIM

SIR HIRAM MAXIM

ELECTRIC LIGHTING. PHOSPHORIC ANHYDRIDE

AS previously stated on page viii, Sir Hiram Maxim became chief engineer and general manager of the United States Electric Lighting Company, and during his tenure of that position he applied for, and obtained, several patents on electrical novelties. These are too numerous to mention here, but they are classified in Appendix II where they will be seen to include lamps, regulators, carbons, carbon holders, commutators, conductors, meters, igniting and other devices.

Of most interest, however, to the general reader, in the natural order of dates, are the improvements brought about in electric lighting and in the manufacture of phosphoric anhydride (P_2O_5), and upon both of these we are able to quote Sir Hiram's personal observations.

" The first arc light ever used in New York

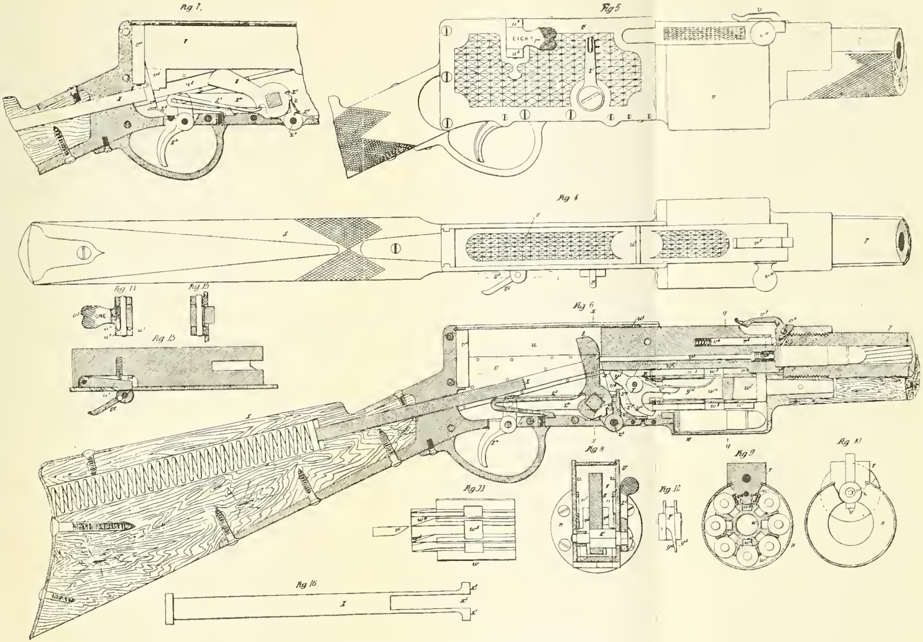
City was one of my own invention, and was put up in the Equitable building. Other similar lights were soon afterwards introduced at the General Post Office, as well as at the large Woman's Home in Park Avenue, New York, and at A. T. Stewart's Grand Union Hotel, Saratoga.

"Early in 1881 I made the first machine for automatically regulating the pressure of an electric light circuit, thus keeping constant the potential or electro-motive force of the current in complete independence of the number of lamps in the circuit. This apparatus was controlled by a separate wire leading from the centre of the illuminated district back to the regulator at the generating station. The machine was illustrated and fully described in the *Scientific American* at the time. I took it and exhibited it at the first Electrical Exposition, held during 1881, in Paris, where it was very much admired, and, for it, the President of the French Republic made me a Chevalier of the Legion of Honour, whilst the Company exhibiting it received a gold medal. The patent afterwards obtained, fully covering this regulator, was numbered 269,805, and bore date December 26th, 1882.

"But the above was not my only exhibit. It was phosphoric anhydride that the manufacture of incandescent lamps called for, as it needed a very powerful hygroscopic material to absorb the water in the vacuum pump. This P_2O_5 is the best-known chemical for the purpose, and it had been prepared in Germany in the following manner: A large glass jar, with a side connection near the bottom, was provided, and this was connected with a dryer, through which pure oxygen was passed freely. A platinum saucer having been placed in the bottom of this jar and the oxygen turned on, the operator took a small piece of phosphorus out of water, touched it to blotting-paper, dipped it in strong alcohol and again applied dry blotting-paper, then dropped it into the platinum saucer, set it on fire and kept the fire going for hours, when there would appear a deposit of lemon-coloured anhydride in the jar. This had to be handled with great care, placed in a smaller jar and treated with bisulphide of carbon to dissolve the metallic or unburnt phosphorus. The yellow colour, however, could never be wholly washed out and the product was always of a lemon or of a pink colour. But while working on electric lights at Bridgeport, Connecticut, after having tried in vain to procure some anhydride and finding myself unable to get it made by local chemists, I decided to go at it personally and to procure it if in any manner possible. I thought over the matter the greater part of one night, got up early the next morning and made drawings of my proposed apparatus, which was made ready by the same evening. It was, of course, put up without unnecessary delay, and I soon was able to turn out phosphoric anhydride in a perfectly pure state and as white as snow. This was done at the rate of a litre a minute and without any oxygen except what I found in the atmosphere. I first converted the phosphorus into a vapour, and blew the vapours into a fine jet where they came into contact with a jet of dry air, and they burnt in a large iron tube, making the tube red hot. The gases and products of combustion entered a large condenser with a conical bottom, the whole being enveloped in a water jacket. The pure chemical fell to the bottom and passed directly into the bottles, which were instantly corked and sealed. For this process I obtained a patent, March 29th, 1881, No. 239,394, and it won for me a French gold medal the same year.

"In 1883 I left the Continent of Europe and came to London. There was a little electric light company in existence at the time known as the Maxim-Weston Company. They owned my patents, amongst which was one which had been filed October 4th, 1878, but was not issued until August 10th, 1880. This latter was for a process of standardizing the filaments of incandescent electric lamps by electrically heating them in a very highly attenuated atmosphere of hydrocarbon vapours, whereby the carbons were made of an exact electrical resistance throughout their entire length. It was the first patent of the kind ever filed in any country. At this period it was the only process known by which a good filament could be made, and it was afterwards used by all the lamp-makers of the world. The Maxim-Weston Company was, unfortunately, in very bad hands. They had no idea of the value of this patent and they did not intend to do any business except to sell out the plant and pocket the proceeds, which ultimately found their way into the hands of the official who wrecked the company. They did not pay up the annuities on the patent and it expired in consequence. Three days after the expiration of the patent, an electrical expert, who knew the value of the patent, attempted to get possession of it, but it was too late, and thus a patent had gone by default that was fully worth at least one million dollars a year. Fortunately, the official who caused all this trouble was ultimately sent to prison, where he served a term of four years."

Full descriptions of Maxim's processes and of the manufacturing works he established for the development of his incandescent system of electric lighting, will be found throughout the extensive articles given by *Engineering* under the following dates: 1880, November 12th, p. 437, and December 24th, p. 604; 1881, June 3rd, pp. 569-570, June 17th, pp. 618-620, and September 2nd, p. 242; 1882, February 10th, pp. 137-138; 1903, May 8th, pp. 610-614.



MAXIM'S FIRST BRITISH PATENT, NO. 3178. JUNE 26, 1883
MECHANISM FOR FACILITATING ACTION OF FIRE ARMS

THE MAXIM AUTOMATIC GUN

SIR HIRAM MAXIM commenced the drawings of his machine gun in a small room which he had hired in Cannon Street, London, E.C., within close reach of the city office of the Maxim-Weston Company, whose works were at Bankside, and, when all his drawings were completed, he fitted up a factory which he had rented at 57D Hatton Garden, corner of Clerkenwell Road, where he could properly make all needed experiments. These having proved successful, the Maxim Gun Company was organized, as already mentioned. His review of operations at this important period cannot better be given than in his own words:

"It was in 1883 that I began experimenting on the automatic gun, and, for it, I obtained my first English patent. It was dated June 26th of that year, No. 3178, its novelty being 'mechanism for facilitating the action of magazine rifles and other fire-arms.' During the ensuing two years I patented every possible means through which the mechanism of a gun could be operated by energy derived from the burning powder.

"Many years before, I had fired a Springfield rifle and I was surprised at the violence and the force of the 'kick.' I conceived the idea that it would be possible to employ this energy to load and fire the arm. I had made designs as early as 1873, but the gun was not actually constructed and tested until some ten years later. Up to this time all guns, machine and others, had been operated by hand. The name of machine gun is applied to any gun which, by means of some mechanism variously contrived, is enabled to send out a continuous fire of projectiles, either through a single barrel or through a number of barrels whether arranged horizontally or about a central axis. The Gatling machine gun, for instance, which was introduced in 1861 by Richard Jordan Gatling (1818-1903) had from 6 to 10 barrels which were set around a fixed axis and which were fired in turn when revolved into position. The cartridges were fed in from a hopper and the mechanism was worked by turning a handle or crank. It is said that it could fire 1200 shots per minute and very frequently discharged as many as 500 shots in two-and-half seconds. The Gardner gun, constructed by Pratt Whitney

& Company of Hartford, Connecticut, was similar to the Gatling, except that its 2, 3, 4 or 5 barrels were arranged in a row like the pipes of an organ. The Nordenfelt gun, which became so popular during the American Civil War, resembled the Gardner in some respects, but, instead of being worked by a crank, it was actuated by a lever. It was invented by Torsten Vilhelm Nordenfelt (b. 1842), who became Chamberlain of Oscar II. of Sweden in 1885, and it was generally considered as being next to the Gatling, the most important of the hand-operated machine guns. It had from 2 to 12 barrels which could be fired either singly or in volleys. It had this great advantage that, in the event of one barrel becoming disabled or clogged, the ammunition supply could readily be shut off from that one barrel and the firing continued with the others. The Hotchkiss revolving cannon had 5 barrels arranged around a central axis, but it had only one lock instead of the ten locks of the Gatling, the motion of which latter was continuous instead of intermittent. It was invented by Benjamin Berkely Hotchkiss (1826-1885), who introduced also a rifling belt and a very popular percussion fuze for projectiles that bears his name, and who, at the time of his death, was considered the first artillery engineer in the world. His revolving gun was the earliest one that was made for a calibre larger than that of small arms. Up to 1888 the factories of Hotchkiss & Company had furnished, throughout Europe and America, over 5,000 guns, of which only two had been deemed failures.

"Until the aforenamed date, 1883, no one had ever, to my knowledge, spent a single penny or made a single experiment in the attempt to evolve an automatic gun. In order to understand the subject, it may be said that an automatic gun is one in which all its functions of loading and firing are performed by energy derived from the burning powder. I saw that there were many ways in which this energy could be employed for working the mechanism of a gun. The first drawings and the first experiments were on a gun in which the cartridge-case moved rearwards in the chamber of the gun at the instant of firing, that is, the powder in exploding drove the bullet out of the muzzle of the gun and moved the cartridge-case back in the chamber a sufficient distance to develop the necessary energy for working the arm. This system has been extensively employed in pistols since that time, but, on not finding it suitable for long bottle-neck cartridges, I devised other plans. In one, I employed a telescopic cartridge; the part moving backwards being short. I also made cartridge-cases with circular corrugations, so that they could expand lengthwise at the instant of firing without being broken in two. It was only necessary that the cartridge head should move backwards a fiftieth part of an inch in order to do all the work necessary.

"In the first gun which I designed, the cartridges were placed in a belt, the same as now, and fed into position by a sprocket wheel, but this gun was heavy and cumbersome, so the next gun I made had a different movement altogether. The action consisted of a crank pin working in a slot instead of having a connecting rod, and the cartridges were fed in, step by step, by reciprocating pawls. This gun worked splendidly, fired at the rate of 666 shots in a minute, and thousands of visitors came to see it, including Albert Edward, then Prince of Wales.

"It was a light and beautiful arm. When, however, I took it out to fire into the open it happened to be raining very hard indeed, and it was then I discovered that the gun would not work at all. On taking it back to my shop I found that it would always stop firing if a small quantity of water was squirted into the mechanism. This was extraordinary.

"I then designed a new action in which a short connecting rod took the place of the slot, and it is this action that has been used ever since—water has no effect upon it.

"I knew very well, while I was engaged on this early work, that others would very soon be trying to get round my patents. I had been a patent expert in the United States, so I knew how to head off these would-be inventors. I accordingly made and patented guns worked by a small piston taking the gas directly from the barrel, others by taking the gas from the muzzle of the gun, and some guns I made in which I used both the recoil and the blast from the barrel. I also made and patented a gun with what was known at the time as a cheese-box feed, that is, it had the cartridges placed in a cylindrical box on top of the arm, exactly the same as we find in the Lewis gun of to-day.

"These numerous patents of mine effectually prevented a great number of lawsuits that would surely have taken place, and I find that, notwithstanding there are many kinds of automatic fire-arms to-day, there is not one that was not anticipated by my early patents.

"Shortly after I arrived in England the

British Government called for a light quick-firing gun to be used against torpedo boats. Two sizes were asked for, a three pounder and a six pounder, and the cartridges were to be 21 inches long. Armstrong, Hotchkiss, and Nordenfelt entered the field. Armstrong made a very heavy gun, and, if I remember rightly, four men succeeded in firing it eight times in a minute. Hotchkiss brought out a gun that was very much lighter and which was fired by four men about sixteen times a minute. Then Nordenfelt produced a gun very much lighter than either and with a breech action that could be worked with greater rapidity, and, I think, four men succeeded in firing this gun twenty times in a minute. It was a thoroughly good and reliable hand-worked gun. I then entered the field, made a light gun with an hydraulic buffer that did not put so much strain upon the mounting; it was what is known as a semi-automatic gun, and I fired it, without any assistance, forty times in a minute. I also made a fully automatic three pounder gun with a belt feed, and, although unaided, I fired this gun sixty rounds in a minute."

"When I attempted to get the fully automatic 37 mm. gun into the service, our military adviser, Captain 'Calamity,' ridiculed the idea in the strongest language. He said that one of the service field guns would put a whole battery of these out of action in five minutes. However, the Boers were of a different opinion. They purchased a considerable number of them, and, when the war broke out, it was found that three or four Boers, concealed in the bush and using smokeless powder, were able to put a whole battery of English field guns out of action in about ten minutes. As a rule they succeeded in killing all the men and horses before the English could find the range or ascertain from what quarter the explosive projectiles were coming. It is impossible to take sight at a sound.

"The Maxim gun has only one barrel. The cartridges are placed side by side between two bands of tape. The magazine is therefore below the gun instead of being on its top—the case with other arms—and, as the belt is not limited in length, the magazine may be very large indeed. The first cartridges are introduced into the barrel by turning the crank handle forward and backward twice. Now, if the trigger is pulled, the primer is struck, the cartridge explodes, and the barrel recoils. The recoil of the barrel and the breech-block extracts the empty cartridge-case and cocks the hammer, while at the same time it stores energy in a spring. The spring in firing off this energy, thrusts a new cartridge into the chamber, closes the breech and pulls the trigger, while at the same time it feeds another cartridge into position ready for the next shot. All the functions are therefore performed by the recoil-energy of the 'kick,' and these various operations follow each other in rapid succession. For instance, if the trigger is pulled and held back for one second, ten cartridges are pulled out of the band, thrust into the chamber, and fired whilst the empty cases are being extracted and expelled from the arm. If the trigger is still held back, the series of operations goes on until the belt of cartridges is finished.

"When it was announced in the public prints that an American electrical engineer had produced a fire-arm which would load and fire itself by simply touching a button, all the energy necessary being derived from the recoil of the arm, the public were incredulous, believing the report much too good to be true. But the little gun was very much in evidence in the experimental factory and shop which I had fitted up in Hatton Garden. His Royal Highness the Duke of Cambridge, then Commander-in-Chief, was one of the first to visit the workshop where the gun was on view. He was, in a short time, followed by His Royal Highness the Prince of Wales, the Duke of Edinburgh, the Duke of Devonshire, the Duke of Sutherland, the Duke of Kent, and many other distinguished people. Lord Wolseley expressed his opinion at the time that this gun could not fail to mark a distinctly new epoch not only in fire-arms, but in warfare, and this has turned out to be true by subsequent events. Society, by the way, ordained that a pilgrimage to Hatton Garden in order to fire the new gun was a thing that must be done, and more than 200,000 cartridges were in consequence expended for the amusement of the 'smart set,' many of whom were anxious to fire it for themselves.

"One of the first orders for the arm was placed by Her Majesty's Government. A gun was specified which should not weigh more than one hundred pounds and which should be able to fire 400 rounds in one minute, 600 rounds in two minutes, and 1000 rounds in four minutes. I produced two guns, each weighing only thirty pounds, and both of which passed the test in exact accordance with the Government specification. I afterwards produced a third gun weighing but forty pounds which actually fired 2000 rounds in three minutes, thus beating all previous efforts, and establishing a record that has never been equalled from that day to this. The British Government purchased the three guns, and gave orders for two more to be sent to Hythe so that they could be tested there in competition with all other forms of machine guns. On the occasion of the test there was provided a very large target of cast iron, which was constructed in such a manner that when struck by a bullet it would make a loud report. The noise that it did actually make was something more like striking a large gong. The range was 600 yards. I placed a belt of 333 cartridges in the gun, touched the button, and the cartridges all went off inside of half a minute. The bullets were found to be all closely grouped in the middle of the target.

"The experiments lasted all the winter, and hundreds of thousands of cartridges were expended. The decision of the Committee was that the Maxim gun beat every other gun at all points, and a very large Government order was in consequence readily placed. It became necessary to establish works in London to supply the demand. I then went into competition with the machine guns of all European countries, and, as I beat every competitor, orders for the gun soon began to pour in from all quarters.

"I had, meanwhile, organized a Maxim Gun Company, with a capital of £75,000. At this time there was a very much larger and very prosperous Corporation in London, known as the Nordenfelt Guns and Ammunition Co. Mr Nordenfelt, seeing that the end of hand-worked guns was drawing near, very wisely approached me, and an amalgamation was entered into, the Maxim patents and the little shop in Hatton Garden being admitted on equal terms with the large works and business of Mr Nordenfelt. The two together were offered to the British public for £1,900,000, and it is said that the total of the shares was subscribed for many times over during the first two hours of the opening of the books.

"Up to this period the Germans had never had a machine gun in their service. The German Government now ordered that competitive trials should take place in which the Maxim gun was to be pitted against all others. At this moment, nothing definite had been decided in regard to cartridges, and the experiments were delayed in consequence for some considerable time. However, the Prince of Wales, when visiting Berlin, spoke freely of the

Maxim invention, and it was suggested that the German Emperor and the Prince should go to Spandau, nine miles west of Berlin, and see the new machine gun fired. Everything was consequently got ready. Each competing gun was provided with 333 cartridges (as nearly as possible the third of a thousand), and the hand-worked guns were the first to be fired. For the last-named guns, two men brought the cartridges and placed them in the hopper, whilst a third man sighted, and still another man either side turned the crank or worked the lever. All these guns jumped about in action. After this the little Maxim gun was brought forward. One man sat down behind it, touched the button, and the 333 cartridges went off in half a minute, the gun remaining all the while as firm as a rock. The Emperor and the Prince visited the targets and found that the Maxim gun had morticed a large hole through the very centre of the bull's eye, while the projectiles fired from the hand-worked guns were 'all over the place.' The Emperor returned, placed his hand on the Maxim gun, and said, 'That is the gun; there is no other.' The Maxim gun was at once adopted into every arm of the service, and has since been extensively used throughout the German Empire as well as into other countries, and it is a matter of history that it went through the Soudan campaign with distinction. At the beginning of the Soudanese troubles the British were armed with Gardner guns, and it very frequently happened that, in the excitement of the moment, the operators turned the handles a little too fast. The cartridges could not settle into position quickly enough, the gun became jammed, and the detachment was sure to be cut down like grain before the reaper. With the Maxim gun it was very different, and, for the first time, the English soldiers were able to thoroughly stop these savage swordsmen in their mad and terrible rush. A great London journalist, when writing of the Maxim gun in the Soudan, subsequently said: ' In the past our wars have been won by the dash, the skill, and the courage of our officers and men, but our last campaign has been won by a very quiet, scientific gentleman living down in Kent.'

" When I was firing a Maxim gun at Vienna, the Archduke William, brother of the Emperor, was present. He spoke English perfectly, and, when I had fired about a thousand rounds without a single hitch of any kind, I approached him and asked: ' Does your Imperial Highness find that the gun fires fast enough and true enough?'

"His reply was: 'Only too fast and too true. It is a marvellous gun, the finest piece of mechanism I have ever seen.' He then went on to say that the Americans were undoubtedly the cleverest mechanicians in the world and the greatest inventors. 'We have a problem at the War Office that perhaps you could solve for us. I will make an appointment and I want you to call on the Minister of War to-morrow morning at eleven o'clock; perhaps you will be able to help us out.'

"Of course I was on hand like a sore finger. The Minister of War, like the Archduke, spoke English perfectly. When he had congratulated me on my great success and complimented the Americans, he said: 'For some years we have been intensifying our field artillery. We are using stronger steel in our guns, making them as light as possible, and at the same time we have increased the length and weight of our projectiles; we have also increased their velocity so that the recoil on firing is very much stronger than it was with our old system, and is very difficult to deal with; in fact, when we fire one of our new high-power field guns we never know where to find it afterwards; it may point in the other direction, the recoil is so strong that the gun runs back a considerable distance after firing; at any rate, it has to be brought up and re-aimed. I have been thinking that you, being a great mechanician, might devise some plan to remedy this trouble.'

"I said: 'Very well, I will take the matter up at once and produce a gun that will give the same velocities and which will not be greatly disturbed on firing.'

"I went back to my hotel, wrote out a specification, and made a freehand drawing showing a gun without trunnions mounted in a cradle, the trunnions being on the cradle, and a powerful hydraulic buffer interposed between the recoiling and the non-recoiling parts of the arm. Instead of the carriage running back on the ground and tearing it up, the energy was absorbed by the hydraulic buffer and the gun was returned to the firing position by a long and very powerful spiral spring.

"I wrote to my company explaining exactly what had taken place, and asked them to put the best draughtsman to work to elaborate my freehand sketch.

"Ten days later I was back in London and attended a Board meeting, and, to my surprise, I learned that nothing had been done in the way of producing the gun—no drawings had been made.

" In presenting at this meeting further details concerning my new plan, I said, ' Gentlemen, instead of the gun and carriage running back at the instant of firing, I propose so to construct the carriage as to allow the gun to recoil as relates to the carriage, to interpose an hydraulic buffer between the recoiling and non-recoiling parts, and to bring the gun back into the firing position by a strong spiral spring. I propose to provide the foot of the trail that rests on the ground with a large and strong steel spade that will be driven deeply and firmly into the ground at the first discharge. By this system, the rate of fire will be increased at least three-fold. You will understand, gentlemen, that the gun recoils in its mounting instead of on the ground and that the energy of the recoil is absorbed by an hydraulic buffer. The advantages are so great that we should lose no time in producing one.

" It was then the turn of our military expert, Captain Acland, to speak, and here is what he said—boiled down :

" ' Gentlemen, I have heard what my co-managing director has to say in favour of his new field gun, and in reply would state that the addition of a hydraulic buffer and heavy cradle and spring would make the guns much heavier than now. Instead of requiring four horses to draw it, it would need six, and, moreover, these additions make the gun very ugly; it completely destroys its neat and graceful shape. Our guns are used solely for parade, we shall never be called upon to use them in actual warfare. No nation on earth would adopt a system that added one ounce to the weight of the complete gun.'

"To this I replied, 'I have been requested by the highest officer of the Austrian Empire to produce such a gun. The addition referred to will not increase the total weight of gun and carriage 15 per cent., while the rate of fire will be increased threefold.' Acland then added: 'I am decidedly opposed to spending a shilling on this gun. It would do our firm much harm in the eyes of the official to present such a ridiculous monstrosity to them. It will never do, drop it and never think of it again.' So the thing was suppressed, but some six or seven years later my semi-automatic gun gave a hint to the Continental nations and they began to leave the trunnions off their guns and to use an hydraulic buffer and spring. At present, what was in that time a much abused and ridiculed system has gone into general use everywhere, with all of the supposed great additional weight and ugliness.

"Shortly after this we had an order for making a lot of 4.7 naval guns; they were very long and gave a very high velocity to their projectiles. They were built up of innumerable pieces of steel, one shrunk on to another. I told the Company at a Board meeting that if they would appropriate £2000 I would produce guns that would stand all the tests required by the Government with half the steel, in half the time, and at half the expense. They appropriated the money, and I put up a tempering plant. I obtained a forging of the barrel all in one piece, had it annealed, rough turned on the outside and completely finished inside; the dividing screw and the rifling were all made bright and smooth. I then placed it in my furnace, and while it was slowly revolving in a very hot wood fire I passed a stream of carburetted coal gas through it. I knew this would prevent the oxydization of the inside, and when it was red hot, the right temperature for tempering, I shut off the gas and opened a very large valve, where I had fish oil under a high pressure, and the cold oil rushed through the barrel so quickly that not more than a pint of it was decomposed. I kept the stream of oil going through until the wood fire was burnt out. The oil that I used passed through a cooler of large size before it entered the big pump that forced it through the barrel. When the gun was nearly cold, I shut off the oil and allowed a stream of water to pass through it all night. Those who were helping me on the job said that the rifling would be spoilt by the high temperature, that the whole inside would be scaled, but when we came to examine it we found that it was only smoked and with a little rubbing it was as bright as silver. I then finished the outside and found that the gun had not been bent in the least, but, by some very careful measurements, we found that the bore was slightly smaller than before the gun was tempered. I knew this would take place and I had allowed for it. When the gun was finished and mounted it was carried to our range to be fired by an experienced artillery officer. He first tested it exactly as they tested the built-up guns, firing increasing charges with very heavy projectiles. When he had finished the usual tests he found that the gun had a smaller bore than before firing, showing that the inside was in a high state of compression and the outside in a high state of tension. I then asked him to fire increasing charges until he had run it up above the tests that were usual for wire guns. He did so, and said that the last shot fired would burst any wire gun ever made. Again it was measured and found that it was still smaller in the bore. All other guns become larger on firing.

"I was very jubilant, and when I attended the next Board meeting I told them what I had done and what the gun stood, and that it was the best gun ever made on this planet and very cheap indeed, but it did not, to my surprise, meet the Board's approval.

"In making and firing very high-power guns I found that the white-hot powder gases cut away the steel quite as fast as a stream of hot water would cut away a piece of ice. On examining the rifling, after a few shots had been fired, I found that the driving side of the rifling that pressed hard on the driving band was not cut away at all, but that the opposite side, where there was a space between the rifling and the copper, the steel was cut away very quickly. It was then very evident that the cause of the erosion was due to a very large volume of hot gas coming against a small surface of steel. The chamber of the gun did not show any signs of erosion. If I could prevent the gases from passing the projectile, the guns would last a great deal longer. I made experiments and found that the life of a gun would be increased fully twenty-fold if the gases were not allowed to pass, and, to remedy this, I made a ring of asbestos and paraffin wax; I put this on the case of the projectile, and placed a steel disc over it, arranged in such a manner that the pressure on the plastic ring of asbestos and wax was 25 per cent. greater than the gas pressure. This, of course, completely stopped the passage of the gas and stopped the erosion in a very marked degree; but when I came to bring it before our Board of Directors our financial man again promptly said it would not do at all. We were steel-makers and gun-makers and it was to our advantage to have the guns wear out as quickly as possible. It was also hinted that certain officials would not like to have the guns last too long for obvious reasons, which may or may not have been true, so that this invention was suppressed.

"Amongst my other gun inventions I must again mention the semi-automatic 6-pounder, which is very much like other 6-pounders, but can be fired with greater rapidity than any arm hitherto invented. In this gun the breech is kept closed during the recoil and it is only opened after the barrel has returned into the firing position. This new feature enables long cartridges to be fired from automatic guns, and it is proven that one of these guns in France fired 40 rounds in 50 seconds with cartridges 21 inches in length. This broke all previous records of quick-firing guns, and the fact probably contributed greatly to my receiving at Paris a personal grand-prix for artillery.

" Altogether, I was granted up to the summer of 1885, thirteen British patents for guns, as well as for their feeding, adjusting and working apparatus. The machine gun patented in America, October 28th, 1890 (No. 439,248), was an improvement on the patents issued in :

England . . .	No. 15,734.	December	1, 1886.
Belgium . .	No. 79,005.	November	15, 1887.
Italy . . .	No. 22,500.	November	26, ,,
France . . .	No. 185,641.	December	14, ,,
Austria-Hungary .	No. 34,166.	April	21, 1888.
Germany . .	No. 44,208.	August	24, ,,
Spain . . .	No. 8,895.	January	25, 1889.

In it was substituted hydraulic apparatus for the mechanical devices that had been previously described. Four of the claims allowed in this 1890 patent in fact permit the employment of two or more hydraulic cylinders and pistons. These act in combination with the sliding barrel communicating with rams connected with the movable breech-block or plug. By this means I have very effectively and readily regulated the speed of firing.

"When I brought out the automatic system of fire-arms, I did not know, nor in fact did I care for, what others had done. Had I known more of the state of the art it would have been much better for me. In the automatic cannon that I made, I employed a peculiar form of mounting. There were no trunnions on the gun itself; they were on a sleeve, cradle or cylinder in which the gun proper was mounted and recoiled. The recoil was checked by a hydraulic buffer, one member of which was attached to the gun and another to the non-recoiling portion. All the attachments for training were on the non-recoiling part, so that when the gun was fired the gunner received no shock; moreover, the strain on the mounting was much less and admitted of a much lighter cone or carriage. The first semi-automatic gun of this kind was shown at Portsmouth, and, not long after, Captain Marrion called on me with regard to it. He said: 'I do not know whether your automatic gun is better or worse than hand-worked guns; some think one and some another; we are not at all agreed, but we are sure of one thing which is that your system of mounting is so infinitely superior to all others that it is bound to go into use all over the world at once. Mind what I say and remember it. Have you got it patented?' Examination at the Patent Offices proved that, while the mountings had been openly shown to the public, the claims related only to automatic guns, and thus was absolutely lost one of the most valuable inventions that could possibly be imagined, solely because the inventor was ignorant of the state of the art and presumed that such a simple and direct system must have already been in use. Since that time Captain Marrion's words have come true, for this form of mounting has gone into universal use."

On December 10th, 1895, Sir Hiram Maxim patented in England a quick-firing automatic gun with Hopper feed, to be used with 3, 6, and 14-pounder guns. This gun fired at the rate of 60 rounds per minute and was well suited to firing on torpedo boats. He had previously patented a range-finding sight for guns as well as the introduction of a steel plate in front of the muzzle of a gun, with an opening for allowing the projectile to pass through, while also employing a powder blast to diminish the recoil.

The admirable hydraulic buffer for checking the recoil of heavy guns, invented by Colonel Clerk, R.A., F.R.S., Superintendent of the Royal Carriage Department in Woolwich Arsenal, is well described and illustrated in *Nature*, June 8th, 1871, pages 105-106. A further account of it is to be found in *Van Nostrand's Engineering Magazine*, February 1870, pages 168-171, the same periodical having previously given (November 1869, pages 984-986) a review of the very able paper on the subject which was read by Colonel Clerk himself before the British Association.

Reference is made to the *Engineer* of January 21st, 1881, pages 42-44, of February 18th, 1881, page 117, and of March 11th, 1881, page 175, for the results of the Machine Gun competition begun at Shoeburyness, January 13th, 1881, between the Gardner 2 and 5 barrels, the Gatling 6 and 10 barrels, the Nordenfelt 5 and 10 barrels, and the Pratt and Whitney 4 barrels. The last-named, *Engineer* of March 11th, 1881, page 178, gives a very detailed account of the Nordenfelt construction more particularly, whilst in the *Engineer* of September 26th, 1884, page 239, and of October 10th, 1884, pages 275-281, may be found a special description of the Maxim self-firing gun; and, in the *Engineer* of June 1st, 1888, page 443, a summary of competitions between the Maxim, the Gardner and the Nordenfelt guns throughout different countries.

Regarding machine guns generally, mention should here be made of the following named publications, which will amply repay perusal, viz.:—

"The Development of Machine Guns," by C. Sleeman, in the *North American Review* for September 1894, wherein he points out the relative merits of the Gardner, Nordenfelt, Gatling and Hotchkiss inventions.

"Machine and Quick-Firing Guns," in *Saturday Review*, May 25th, 1889, pages 635-636; and "The Maxim Gun," in *Saturday Review*, November 30th, 1889, pages 615–616.

"Rapid Firearms," by Lieut. William W. Kimball, U.S.N., and others, in *Engineering* for 1888, pp. 27–29, 147–8, 196–7.

"Modern Guns and Gunnery," by Brevet-Colonel H. A. Bethell, who describes fully not only the quick-firing guns of different nations, but who details also explosives, such as ballistite, cordite, gun-cotton, lyddite, melinite, picric acid, etc., as well as fuzes of different construction.

"A Century of Guns," by H. J. Blanch, 1909, wherein he refers to the arm patented in 1883 by Hiram S. Maxim, who, says he, applied the principle of auto-loading to a variety of guns, rifles, and pistols.

Chambers's Journal, vol. lxiv., page 190.
Current Literature, vol. xxix., page 23.
Engineer, April 23rd, 1897, pages 414–417.
Harper's Weekly for May 21st, 1904; August 6th, 1904; also vol. xlviii., page 1217.
Independent, for March 21st, 1901.
Industries and Iron, for March 20th, 1906.
Journal of the Military Service Institution, vols. xxii. and xxiv.
National Review, vol xii., page 583.
Nature, of March 5th, 1885, pages 414–416.
Saturday Review, vol. lxviii., page 615.
Scientific American for August 5th, 1916; September 23rd, 1916; November 25th, 1916.
Scientific American Supplement for September 23rd, 1916.

For details and engravings of the early forms of the Maxim guns, reference is made to *Engineering* of February 11th, 1898, in which it is said that Sir Hiram Maxim divided automatic guns into three classes. All of these are fully explained, as are also the many patents issued to him during 1883, 1884, 1886, 1887, 1890, etc.

Fig. 1.

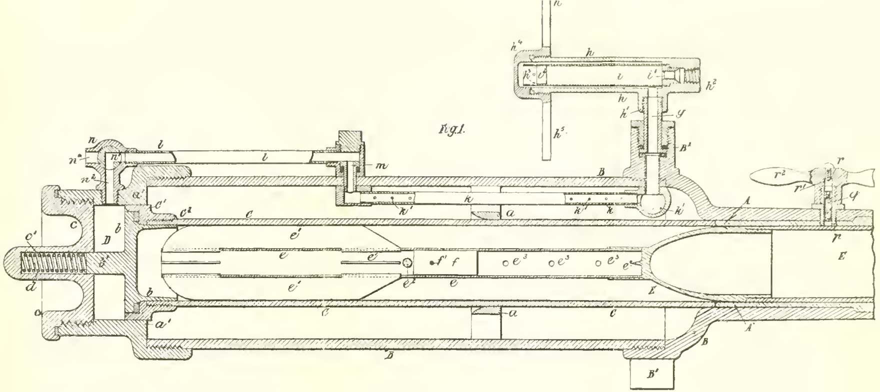
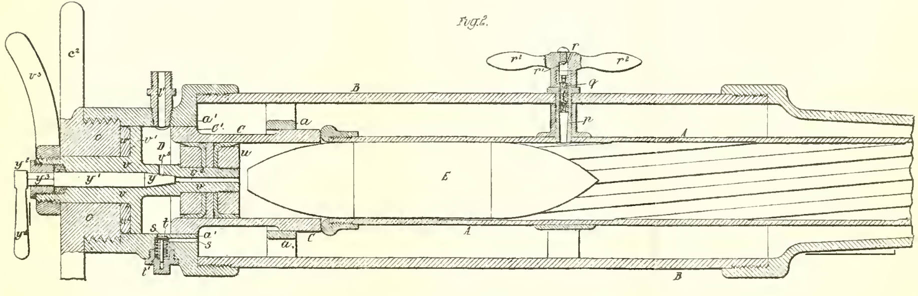


Fig. 2.



PATENT No. 17252. DECEMBER 15, 1887
MAXIM'S IMPROVEMENT RELATING TO DYNAMITE GUNS

POWDERS

1884–1885. SLOW-BURNING POWDER
June 1885. MODIFYING BLACK POWDER
1884–1885. AERIAL TORPEDOES
1886. SMOKELESS POWDER

BY reference to Appendix II, it will be seen that the British patents obtained by Sir Hiram Maxim from June 26th, 1883 to January 8th, 1885, were twelve in number, and that they covered improvements in guns, rifles and other fire-arms, as well as cartridges therefor, and novel processes for their manufacture, etc.

On January 14th, 1885, patent No. 552 was taken out by him for "improvements relating to the manufacture of gunpowder and to cartridges or charges containing or formed of the same." In these cartridges, Sir Hiram Maxim employed four varieties of powder which were made to act progressively; the diameter of the slowest burning grains being about one half-hundredth of an inch and that of the quickest burning grains one ten-thousandth part of an inch. This was followed by patent No. 2090, issued February 14th, 1885, for other improvements in cartridges again containing black or brown powder of progressive burning and having multiple perforations. Sir Hiram's next patent, No. 6591, May 30th, 1885, claimed "improvements in guns and explosive projectiles therefor, chiefly designed for destroying ships." This was for a very large gun intended to throw aerial torpedoes, and, as will be seen further on (at page 76), a progressive black or brown powder was again provided for and a delayed action fuze was employed for the first time.

As the above prepared the way for Sir Hiram's introduction of smokeless powder, which, in the minds of many, is an invention hardly second to that of the automatic gun, his different notes on the subject of powders will necessarily be welcome:

"It was in the year 1885 that I first commenced to experiment with powders. My early experiments were for the purpose of making black powders which would not be hygroscopic. I also experimented with a view of making a stronger powder and for using chlorate of potash as an oxygen-bearing salt. These early experiments demonstrated that even chlorate of potash could be tamed and good and reliable explosives made, providing that a considerable quantity of ordinary paraffin wax was present in the mixture. It was also found that a certain amount of carbon could be displaced in black powder by paraffin wax, and that the paraffin wax not only enabled the compound to be pressed into shape with greater facility, but to a considerable extent prevented the absorption of moisture.

"I learnt very early in my experiments that all high explosives failed completely to detonate in a high vacuum. Even fulminate of mercury burns slowly, the flame resembling to some extent that of alcohol in the atmosphere.

"In the winter of 1885-6 I experimented with a view of using some forms of nitro-glycerine compound as a bursting charge in shells. I obtained a quantity of a very hard and stiff gum made from nitro-glycerine and soluble gun-cotton, and this I squirted through dies into threads, and, curiously enough, these threads do not vary a thousandth of an inch from the British Government cordite used in small guns to-day, whilst the threads themselves have exactly the same appearance. But this was never claimed by me as a smokeless powder, because at the time I used it only as a bursting charge.

"In 1888, when I seriously took up the question of smokeless powder, that is, powder to be used as a propellant instead of as a bursting charge, I understood fully the two dangerous elements—gun-cotton and nitro-glycerine—that I had to deal with, and my researches were conducted with a view to ascertaining how these violent explosives could be modified. I was provided with a well-equipped laboratory, and had all the guns and other appliances necessary to carry on my experiments in a very thorough manner. Having found that all sorts of explosives could be modified by the addition of paraffin wax, I experimented with various kinds of oils, such as vaseline, cylinder oil, sweet oil and castor oil. Everything considered, it was thought by me that castor oil was the best. This, however, was only true as far as compounds containing small quantities of nitro-glycerine were concerned; with the high percentages of nitro-glycerine we found it better to use some heavy petroleum product, such as cylinder oil or paraffin wax. It will be seen by examination of my patents that I was experimenting with petroleum products more than a year before any mention was made of these products by Messrs Dewar and Abel. It will also be seen that I patented the identical mixture claimed by them, fourteen days ahead of their patent.

"At the time I was experimenting, during the year 1888, it occurred to me that the molecular wave of detonation that passed through nitro-glycerine in exploding, would not have the same amplitude as the wave which is set up in gun-cotton when it detonates, and it occurred also to me that if there were a considerable difference in the amplitudes of these waves, in a compound of these two elements, the conflict between the natural period of vibration of each would so interfere with one another that a compound of the two would be very difficult to detonate. My experiments demonstrated this to be true. I used all possible compounds between 1 per cent. and 60 per cent. of nitro-glycerine with the gun-cotton.

"But I did not wish to rely altogether upon preventing detonation by wiping out the violence of the nitro-glycerine through another sort of violence which was found in gun-cotton. It occurred to me that as paraffin and oils had shown themselves so efficacious in other compounds, they might be of considerable value in ensuring against detonation in smokeless powder, for a considerable quantity of combustible material in the powder really greatly reduces the quantity of carbon di-oxide evolved, and consequently the temperature, which, in its turn, prevents destructive erosion of the gun.

"Admitting it to be true that the wave of detonation in gun-cotton is different from that in nitro-glycerine and that one does neutralize the other to a considerable extent in preventing detonation, it may be assumed, I think, that, in order to reap the greatest benefit from this physical fact, the two elements should be combined approximately in equal proportions. In adding oil or hydrocarbons to my smokeless powders, I was governed in no small degree by my knowledge of the explosiveness of various compounds.

"It is well known that if finely-divided charcoal, sawdust, starch, flour, or sugar is combined with dry air in proper proportions and ignited, the compound will explode with sufficient force to completely wreck a building. This has often occurred. We know that a much more violent explosion results from the explosion of common coal gas mixed with atmospheric air in proportions of 10 to 1. In this compound there is an intimate mixture, and the violence of the explosion is very great.

"Suppose now that we combine pure hydrogen gas, or, for the matter of that, a hydrocarbon, with pure oxygen, eliminating the nitrogen, we shall find the explosion still more violent. It will therefore be seen that the presence of nitrogen in the compound diminishes the violence of the explosion. If we take gasoline or naphtha and combine their vapours with atmospheric air, in the proper proportions, we also obtain a violent explosive, while pure oxygen and the vapours of petroleum detonate with nearly the violence of fulminate of mercury.

"Suppose that we place any of the light products of petroleum in a little retort, heat the retort, and drive the vapours off through a jet. If we allow this jet to pass through a tube, after the manner of a Bunsen burner, sucking the air after the jet and discharging it combined with the air at the other end of the tube, we shall find that all the products of petroleum will produce an explosive gas which will burn with a blue flame. Before this mixture is lighted it is perfectly transparent, the air combining with and dissolving the vapours before they are condensed into a liquid.

"Suppose now that, instead of the light products of petroleum, we fill our retort with a good quality of kerosene oil (by good quality I mean one that is quite free from naphtha) we find that we have to greatly increase the temperature of the retort before this oil is converted into a vapour. We then find when it is converted into a vapour, that instead of being dissolved in the air and producing a transparent mixture, it is cooled without being dissolved—the oil, in coming in contact with the air, at once assuming a liquid form, that is, being condensed back into liquid again and appearing in the air in a highly divided condition. Of course, each little particle of petroleum has assumed a spherical form, and what was a colourless mixture with the light grades of petroleum becomes a very dense and white cloud. Here we have a highly combustible material—in fact one which is considerably more combustible than either sugar, charcoal or starch—thoroughly mixed and combined with atmospheric air. Anyone would suppose that, if a flame were applied to this dense cloud, the mixture would at least explode. But such is not the case; it will neither ignite nor ex-explode.

"Suppose now, that the air which is being sucked in at the base of the Bunsen burner or injector, is heated. As the temperature mounts, the white cloud becomes less and less dense until the temperature of the boiling oil is reached, when the compound becomes perfectly transparent. If a flame be then applied, it burns exactly as the lighter grades of petroleum burn at a lower temperature.

"Why is it, then, that when the oil is in a highly divided condition in cold air, the compound refuses to explode?

"As before stated, each little atom of oil is in spherical form suspended in the air. Now, before this little atom can be burnt, it has first to be transformed into a vapour. This requires a considerable amount of heat and requires time, in fact, so much heat and so much time that the flame absolutely refuses to pass through it. It will be readily understood that if heat be applied to kerosene oil, the first effect will be to convert it into a vapour, then it has to mix with the air, and after that it explodes.

"These experiments led me to believe that a considerable quantity of paraffin wax or carbonaceous material combined with smokeless powder would be an insurance against detonation. As the natural tendency of nitroglycerine and gun-cotton is to detonate, I wished to have as many guarantees as possible against their asserting their true nature. Hence the addition of carbonaceous material.

"In my experiments I wished to know what the effect of di-nitro-cellulose would be when combined in various quantities with smokeless powder.

"I therefore went to a firm of wholesale chemists in London, who make a speciality of pure di-nitro-cellulose—considered to be the best that can be obtained in the world. I combined this in various proportions and subjected it to the heat test. I also sent quantities of it to the United States of America, to see how it would keep in the American climate. The result was anything but satisfactory; one American summer not only ate up the bag containing the powder, but also the tin case holding the bag. It was found that the di-nitro-cellulose was much more apt to detonate, especially when tested at a high temperature, than true gun-cotton. Specimens of my powder containing 25 per cent. of nitro-glycerine were sent in considerable quantities to Russia and Mexico, and, after four years, it was found that the cold had no effect, and that the portion which was returned from Mexico produced the same results, when tested, as when it was quite new. But the nitro-glycerine and the gun-cotton employed in this powder was prepared with very great care, the powder being able to stand the Abel heat four times over without showing any acid reaction.

"There is another reason why I prefer to have some carbonaceous material in smokeless powder. It is found by actual experiment that both the ballistite used on the Continent of Europe and the British Government cordite erode the gun with great rapidity. With ballistite, although the nitration of the cotton is not so high, and although the percentage of nitro-glycerine is 40 per cent. as against the British Government 58 per cent., the actual erosion which takes place is perceptibly greater than with cordite. This arises from the fact that the British cordite contains 5 per cent. of cylinder oil, which transforms a considerable quantity of carbon di-oxide into carbon monoxide. It is a well-known fact that the specific gravity and density of carbon di-oxide is very much greater than that of carbon monoxide. A moment's thought will convince anyone that a light gas is preferable to a heavy gas in a fire-arm. In order to produce a given pressure with a given weight of carbon di-oxide, it is necessary that its temperature should be very much higher than when the lighter monoxide is employed. It will, therefore, be seen that when the carbonaceous material of smokeless powders appears in the products of combustion as carbon di-oxide, the temperature must of necessity be very much higher than when the carbon is simply converted into carbon monoxide, and experiments have shown that the erosive effect of gases upon the bore of a gun are very much greater with the di-oxide than with the monoxide.

"Professor Vernon Boys was employed by our firm to conduct a series of experiments on erosion. The apparatus had been made under my directions. A very large and strong steel block had been bored out and tempered from the inside. It was of very tough steel and would stand a tremendously high pressure. This apparatus was provided with a pressure-gauge. The erosion was produced by blowing the gases at a very high pressure through a steel nozzle, the nozzles being carefully weighed before and after each test. With a powder containing only 13 per cent. of nitro-glycerine and oil the erosion was rather less than a fourth as much as with Government cordite containing 58 per cent. of nitro-glycerine with oil, with the same pressure of escaping gases. It will, therefore, be seen that the erosion was just about in proportion to the quantity of nitro-glycerine employed.

"Smokeless powder may be moulded into many shapes; if in spheres or cubes, the burning surface is very rapidly diminished as the powder is consumed, that is, the reduction of the size of the grain takes place very rapidly. If the powder is formed into cylinders one diameter in length, it is very obvious that not only would the cylinder become one diameter less in burning, but also that it would be shorter. When, however, the powder is spun into sticks many diameters in length, the burning surface only diminishes with half the rapidity of spheres or cubes.

"If the powder is spun into tubes and cut into proper lengths, it burns from the inside and outside at the same time, thus keeping the burning surface uniform. The relatively large and thin squares of powder used by the Nobel factories (ballistite), and the long and thin strips employed in Russia, are not rapidly diminished as the flakes and sheets are consumed.

"Many have imagined that it would be advantageous to spin smokeless powder into multiple perforated sticks, in such a manner that the burning surface of the powder would be increased instead of being diminished as the projectile moved forward in the bore of the gun, and it is believed that this form of powder would give higher muzzle velocities with a given pressure than any other form of powder.

"I believe that the British authorities at Woolwich were the first to experiment with this form of smokeless powder, but the results were not favourable. I was the first to patent multiple perforated powder in England, and I was also the first to experiment with transversely perforated sticks of powder in a large gun. Our experiments demonstrated that when relatively large sticks were transversely perforated, they gave good results if only three-quarter charges were employed, but as soon as any attempt was made to increase the charge and bring the muzzle velocities up to a point which was easily obtainable with smaller sticks, it was found that the pressure became erratic and in some cases dangerously high. This was particularly noticed when the charge was heated to 100 degrees Fahrenheit before firing.

"The theory has been advanced that when a certain pressure and rapidity of burning have been reached, the evolution of gas in the perforations becomes sufficiently violent to blow the sticks and grains of powder into fragments, and that this accounts for the erratic action and enormously high pressures which seem common to this form of powder. I do not pretend to deny that this form of powder does explode and is broken to bits by the rapid evolution of gas, but it is not necessary that this should occur in order to develop high and dangerous pressures.

"It is a well-known fact that smokeless powder burns with extreme slowness in the open air; it is also a well-known fact that the rapidity of burning is greatly increased by pressure. Suppose we ignite a charge of smokeless powder in a large gun. At first the burning is relatively slow. As the gas is evolved and the pressure is increased, the rapidity of burning is also increased. The rapidity of burning in its turn greatly increases the pressure; the one reacts on the other in rapid succession, until in the mere fraction of a second the combustion becomes extremely rapid. We, therefore, have two agencies, one working on the other, which tend to increase the rapidity of burning, but as the projectile moves forward in the gun with accelerating velocity, it provides more space for the gases. At the same time, if solid powder is employed, the area of the burning surface is decreased, which also tends to diminish the evolution of gas; we therefore have two agencies which tend to increase the evolution of gases, and two agencies which tend to diminish the evolution of gases, and it is found in practice that if the stick or grain of powder is of sufficient size, that the slowing up agency caused by the reduction of burning surface together with the moving forward of the projectile, are sufficiently rapid not to be overtaken by the other increasing agencies referred to.

"Suppose now that we form our powder into finely perforated sticks. In the ignition of the charge the fire enters the small perforations at once, and burns them larger with great rapidity. The actual burning surface of the powder is therefore increased as the projectile moves forward in the gun, instead of being decreased as is the case when solid powder is employed. We then have three agencies each reacting upon the other, and all of which tend to increase the rapidity of burning, and only one agency, namely the movement of the projectile in the gun, which has a tendency to diminish the evolution of gases. Is it not apparent, then, that the three agencies working together should overtake the single agency in the gun which tends to diminish the evolution of gas. This theory is very fully borne out and proven in the experiments carried out by the British Government some years ago. A large quantity of cordite such as is employed in small-arm ammunition, was piled up in a field, and ignited at the top. It first flared up like so much petroleum, the rate of burning very rapidly increasing. As the gas was evolved it produced an increased pressure on the burning surface, and this increase of pressure caused the powder to burn with still greater rapidity ; the one reacted on the other in rapid succession. The flame was driven down into the interstices between the threads of powder—in reality one might consider this pile to have been a very large and finely perforated grain of powder. The fact that it consisted of a large number of separate pieces not fastened together, counts as nothing. The tensile strength of the material at these enormously high velocities is as nothing when compared with the inertia of the mass. When about one-quarter of the powder had been consumed with increasing velocity, the remainder detonated like so much nitro-glycerine, and excavated a hole in the earth 15 feet in depth and 24 feet in diameter. The violence of this detonation broke a great number of windows within a radius of one mile.

"I have already shown the influence that oils and hydrocarbons have on smokeless powder. I have also shown some of the peculiar phenomena relating to the mixture of kerosene oil and atmospheric air. I now propose to point out how smokeless powder may be made and used in large guns. The gun-cotton and nitro-glycerine that one can obtain in England are of great purity; it is a simple matter to make nitro-glycerine in almost any civilized country of the world. But it is not a simple matter to produce a high grade of gun-cotton quite free from impurities and unstable products even in England. Assuming, however, that both our nitro-glycerine and our gun-cotton are quite pure and stable and of the very highest possible degree of nitration, it will not be necessary for me to describe at length how these products are obtained. I will only assume that they are obtainable, and proceed to describe how I form them into smokeless powder suitable for large guns.

"I take 44 lbs. of nitro-glycerine and 46 lbs. of wet pulped gun-cotton (not counting the water). These two are thoroughly mixed in the ordinary way. The Government mixes the two products by hand. They may be also placed in a large wooden box and rotated. When the nitro-glycerine has once come in contact with the gun-cotton they are not easily separated, in fact, the water may be squeezed out of the compound without displacing the nitro-glycerine. There should be about 30 per cent. of water present in the charge; in this condition it may be kept for quite a length of time, and it is perfectly safe. A compound of this kind is really a species of wet and safe dynamite, but it is called paste in England, and I will adhere to that name.

"Sufficient paste is placed in an Edge mill, so that, freed from its water, there will be 46 lbs. of gun-cotton and 44 lbs. of nitro-glycerine. More water is then added till the whole compound is of the consistency of cream or mortar, and then 8¾ lbs. of finely pulverised rosin is added. The Edge mill is then started, and when the whole mass has been ground for about three hours, I add 1¼ lbs. of heavy petroleum cylinder oil, such as is used for lubricating cylinders of steam-engines. Grinding is then continued for two hours, making five hours in all. The charge is then withdrawn from the mill and placed in a centrifugal machine, or it may be placed in a bag and the water squeezed out. This grinding deprives the nitro-glycerine and gun-cotton and also rosin of all traces of free acid, and it also thoroughly combines and mixes the ingredients. It likewise greatly reduces their bulk.

"The charge is then broken up into lumps of about the size of small nuts and placed in a drying house to be deprived of its water. When quite dry, it may be placed in a hermetically closed cylinder, and the air pumped out, and its place supplied with vapours of acetone. When the weight of the mass has been increased by about 25 lbs. the acetone vapours may be shut off, and the compound kept in the closed cylinder for a few hours.

"Another process is to sprinkle the acetone on the dry powder, and then compress the whole in a brass case having an air-tight cover. The acetone will very quickly diffuse itself through the powder, and in a few days the compound, which we sometimes call the 'cheese,' will be ready for use. The cheese should be of sufficient size to fit in the cylinders of the press. The press consists of a large gun-metal cylinder, with vertical trunnions; the cylinder has a partition in the middle, and has a species of cock which opens various holes of different sizes. The charge, or cheese, is placed in one of the cylinders, both pistons of which are by hydraulics moved forward until the mouths of the cylinders are closed; we shall then have our cylinders communicating by holes in the partition. The two outer ends of the cylinders being closed by their respective pistons, one cylinder will contain the cheese, while the other is quite empty. The empty cylinder is then connected with the air pump, and the cheese is pressed through the holes in the partition by means of the hydraulic piston. In passing through this partition it is deprived of its air. The second piston is then allowed to move forward, thus compressing the mass, and again forces it through the partition, thus causing the first piston to move back.

"The mass having been deprived of its air, the air pump is shut off, and the charge is forced through the partition first by one piston and then by the other. Gauges on the hydraulic press indicate how much pressure is required, and it is found best to keep the pressure rather high, by closing some of the holes in the partition, whilst forcing the paste backwards and forwards. This repeated squirting of the paste through the holes in the partition is found to thoroughly incorporate the mass in a very short time, and when it is observed that the mass is sufficiently homogeneous and plastic to pass through the small holes with little pressure, the cock in the partition is turned in the right direction to bring both cylinders in communication with the spinning die. Then, when one piston is held in position by hydraulic pressure, the other is moved slowly forward, spinning the mass into one or more rods as required. This process is very quick and efficient and does not waste acetone.

"It may be advantageous to employ rather large sticks of powder in guns, larger in fact than can be consumed if the rods are cylindrical, and, when desirable, I arrange four or more sharp edges, which cut sharp V-shaped grooves into the powder as spun from the die. These grooves should be one-fifth of the diameter of the stick of powder.

"By making these grooves, we have eight or more sharp edges running the entire length of the stick. This enables the stick to be evenly and easily ignited, and as the powder is consumed faster at the bottom of the V-shaped grooves than anywhere else, the stick, when about half consumed, is divided into four or more sticks. We have, therefore, the advantage of having sticks which keep their place in the gun better, and which when, being consumed, are cut into smaller sticks by the action of the gas itself."

Slow-burning Brown Powder

"My first experience with powders came about in the following curious manner: I had been notified from the War Office that a large number of high officials would visit my little experimental laboratory at 57D Hatton Garden, London, on the following day, with a view to seeing my new automatic gun fired.

"On the next morning, at about half-past ten o'clock, a large number of officials put in an appearance, and a considerable number of rounds were fired in order to demonstrate the automatic action of the gun. After remaining in the place for rather more than an hour, they all departed, with a single exception, the exception being Lieutenant-General Sir Andrew Clarke, Surveyor-General of Fortifications for the British Empire.

"Sir Andrew informed me that he would like to have a little private conversation with me, and, upon going into my private office, he commenced by saying that he was an Irishman, and that he had a great admiration for Americans. He said that there was no question but that we were a very clever race. He had admired the automatic gun very much indeed. It was certainly a new departure, but, he said, it should not be put together with screws, every screw ought to be eliminated from the mechanism. And I assured him that this should be done at once.

"Then he said: 'I believe, Mr Maxim, you are a very clever fellow, and I should like to have you come to my office to-morrow morning at 10 o'clock, and see if you are able to assist me in unravelling a certain riddle. I believe you can do it.

"I accordingly put in an appearance the next morning at exactly 10 o'clock. Sir Andrew then said: 'Mr Maxim, the Germans have made a cannon powder which they call "brown prismatic." It is an extremely good powder as it produces high velocities with relatively low pressures. We have analysed this powder, which is a very easy matter, and have found out exactly what its constituents are, and we have made powder having exactly the same amount of nitrate of potash, imperfectly burnt carbon, and sulphur, as is contained in the German powder. We have done this with the greatest care, but when we try our powder we find that it produces high pressures and low velocities—quite the reverse of the German powder. We have gone into this matter in a very thorough manner. We have had the assistance of the cleverest scientific men and chemists in the Empire. They all agree exactly as to what the German powder is made of, and how much of each constituent it contains. However, the German powder always produces high velocities and low pressures, and ours as uniformly produces high pressures and low velocities. Of course there can be no patent on the powder as it contains nothing new. Still, the Germans ask us to pay them £35,000 for the secret, and as we are quite unable to find out what this secret is, we are on the point of paying them this large sum of money. I have thought, however, that perhaps you can assist us in the solution of this question, and save us the money. Do you think you can.'

"To this question I replied: 'Sir Andrew, you have already told me the difference between the two powders in language which I understand thoroughly. I will come back again to-morrow morning at the same hour, and I will then tell it to you in language which you cannot fail to understand.' He said, 'Impossible'; but I said, 'Indeed, it is quite true.' 'But,' said he, 'how have you so readily found it out?' I rejoined: 'Suppose I had come into this room, and that there were two hats on the table, and you assured me on your word of honour that there was an orange under one hat. If I should lift one of the hats and found it had no orange under it, I should be dead sure that the orange was under the other hat, and this without seeing the orange. I will come to-morrow morning and show you the orange.'

" When Sir Andrew was telling me with what care they had analysed the powder, I knew at once that there could be no mistake in this direction. I knew it could not be a chemical difference, therefore it must be a mechanical one. I then asked myself what I should do if I wished to produce a slow-burning powder, and it occurred to me that the best way to do would be to have the nitrate of potash, which was the source of oxygen, coarse and granular, so that the oxygen would have to travel further in order to come into contact with the combustible material. I asked Sir Andrew to give me a prism of the English and a prism of the German powder, which he did. I then returned to my laboratory, and after having obtained a micrometer to go with my microscope, I polished one of the flat surfaces on both prisms of powder. Upon placing the English powder under the microscope I found that the nitre, the carbon, and the sulphur were so finely ground and so intimately combined, that it presented one homogeneous mass of uniform colour. The highest possible power that could be employed on an opaque body failed altogether to show the individual particles which made up the cake. It was therefore evident that it had been very finely ground indeed. Upon putting the German powder under the microscope, however, it was exactly as I had expected. It had the appearance of hogshead cheese. The sulphur and the carbon were finely ground and intimately mixed, but the nitrate of potash was granular, the largest of the grains being five-thousandths of an inch in diameter, and the smallest about half a thousandth. This, of course, revealed the secret, and the next morning I was promptly on hand at Sir Andrew's office with my microscope and the polished blocks of powder.

"I first showed Sir Andrew the English powder, and called his attention to the fact that it was quite impossible to see any granular appearance at all. I then placed the German powder under the microscope, and he saw the difference immediately. He said: 'It looks like brawn'—brawn being the English name for hogshead cheese.

"This was a perfect solution of the question, and Sir Andrew complimented me very highly. He said: 'Now, Maxim, how do you account for this? We have here in England some of the cleverest men in the world—Sir Frederick Bramwell, Sir Frederick Abel, Professor Dewar, and so on. They have examined this powder with the greatest of care, and have actually given the thing up. We then called upon you. You do not pretend to be a chemist at all, yet you arrive at the solution of the mystery inside of twenty minutes.' In reply to this I said: 'The others assumed that there must be a chemical difference, and they examined it chemically. I made up my mind from the first that it was a mechanical difference, and I was right; all I required to show that I was right being my microscope.'

"Some years after this, in speaking on the same subject, Sir Andrew said: 'You did us a very good turn, Maxim, in finding out what that powder was, but our clever men,' he didn't mention names, 'will never forgive you for what you did with your little microscope.'

"Shortly after I had demonstrated what the German powder was, I visited Hall's Powder Works and had a batch of powder made. I first placed in the grinding machine the sulphur and the charcoal, and these were ground together for about two hours, being thus very finely and evenly mixed. I then weighed out the nitre, which was in a granular form, and about as coarse as beach sand. This was thoroughly mixed with the sulphur and the charcoal, and the whole slightly damped in order to prevent the dust from escaping. The mill was then started, and when the grinding had proceeded five minutes I took out a specimen, and I continued to do this every five minutes during two and a half hours. I thus obtained a large number of different grades of powder. Upon trying these, it was found that we had all degrees of slowness. The batch which had been ground only five minutes would hardly go off at all. That which had been ground fifteen minutes was very slow burning, and that which had been ground about twenty minutes appeared to be identical with the German powder, whilst that which had been in the mill for two hours was extremely violent. This was, therefore, a complete solution of the question, and afterwards I made cakes of powder in which several grades appeared in the same charge or cake, arranged in such a manner that the slow-burning powders were the first to take fire, and the quick-burning the last.

"These experiments took place in the winter of 1884-5."

Modifying Black Powder

"On the eighth day of June 1885, I took out British patent No. 6926. This patent relates to modifying ordinary black or brown powders.

"When ordinary black powder is compressed into large grains or blocks for employment in artillery, it has been found that the density of the outside of the cake is considerably greater than the density of the inside, showing that black powder does not flow freely under high pressure. Compressed black powder is extremely brittle, so that when large charges are loaded into a cartridge-case or bag, the friction of the pieces together produces powder dust in considerable quantities, sometimes sufficiently great to produce high and dangerous pressures. Moreover, great trouble has always been experienced in keeping constant the quantity of water contained in powder. It has been found that black powder is hygroscopic, that it absorbs water in damp weather and gives it off in dry weather, and that the ballistics are greatly influenced by the humidity of the powder. The object of my patent was to improve common black and brown powders, and to obviate the troubles which I have enumerated.

"It was found that when a very small quantity of paraffin wax was mixed with powders, the powder flowed with much greater facility under the press, that it was rendered less hygroscopic, that the grains were tougher, and that the liability to be reduced to a fine powder was considerably diminished. But as paraffin wax is a material which requires an immense amount of oxygen for its complete combustion, it was found best to mix with the paraffin wax sufficient oxygen for its combustion, and also a certain quantity of sulphur. In this way experiments were greatly simplified, because no matter how much of the compound was placed in the black powder the relative amount of oxygen would always be right. I therefore made a mixture consisting of:

78.18	nitre
11.42	paraffin
10.40	sulphur
100.00	

"A powder of this kind is not easy to ignite, but if properly confined and ignited it goes off with considerably more violence than ordinary black powder. However, if we mix one part of this with nine parts of common black powder, while it is still being ground under the Edge mill, we shall have a powder which, for artillery purposes, is better than any other powder in use. But it is not necessary to adhere to the formula which I have given. For instance, if one pound of paraffin wax is intimately ground with five pounds of nitrate of potash, it produces a white explosive which can be safely stirred up with a white-hot iron, and which can only be set off by a very powerful detonating charge. This mixture answers very well to mix with common powders, and produces excellent results.

"Suppose now that you should take one pound of this compound and combine it with one pound of common black powder. The mixture would not differ much in appearance from ordinary black powder; still it would have many physical properties peculiar to itself. It could not be set off with a spark. It would stand a great deal of hammering and knocking about without going off. I do not think, however, that a mixture of this kind would be suitable for the bursting-charge of projectiles. I should say that the addition of from 10 per cent. to 25 per cent. of the compound would be ample to impart to ordinary black powder a sufficient degree of insensitiveness to prevent its going off prematurely in a shell. But it would require a detonating charge considerably stronger than is necessary to set off pure black powder, and I have designed a shell and fuze for this purpose. Naturally there is always some danger that extremely high pressure behind the projectile may force the flame into the powder chamber, and in order to obviate this, I have placed on the rear end of the projectile a cap, and interposed between this cap and the projectile a semi-plastic band or washer, which is subjected at the instant of firing to a pressure several tons per square inch more than the pressure in the powder chamber, thus practically doing away with all danger from the passage of flame, whilst at the same time the paraffin wax makes it impossible for the black powder to be ignited by the shock due to discharge."

Aerial Torpedoes

"In the winter of 1884-5 there was a good deal of discussion going on in military and naval circles in London regarding the efficiency of the Whitehead torpedo. It was believed by many that this form of torpedo would not prove anything like as effective as had been supposed ; in fact, that it was very much overrated, and that it might not be very efficient in actual warfare. At that time Mr Bryce Douglas was the Chief Engineer of John Elder's Shipbuilding Works at Glasgow. Bryce Douglas was not only an engineer, but had been a sea captain for many years, and he expressed himself very strongly of the opinion that torpedoes and torpedo boats would be found in actual warfare to be of little or no value. In the first place, he said, the high speeds claimed for torpedoes had always been attained under extremely favourable conditions, and that if these same boats were tried under service conditions, it would be found that their speed, instead of being greater than that of cruisers, would be considerably less ; in fact, he said that a good many of them would not be able to make ten knots an hour in a heavy sea. Then again, he did not believe that the submarine locomotive torpedo would be efficient. He said that such torpedoes were launched from a moving vessel into a rough and swirling sea, and he did not think that under such conditions they would stand much chance of hitting an enemy moving at a high speed through rough water. He was of opinion that in a sea fight these torpedoes would be quite as dangerous to a friend as to a foe.

"At that time Messrs Thomas and Albert Vickers, Mr Robert Symon, Mr Brodrick Cloete, and Mr Bryce Douglas were included in the syndicate which was working on the Maxim automatic gun, and they wished me to study the question of torpedoes with a view to developing something which would be better than the Whitehead system.

"Bryce Douglas was of the opinion that it would be much easier to throw a torpedo through the air than to propel it through the water. At that time the Whitehead torpedo was launched from a tube by the action of gunpowder. Why not make the tube longer, and instead of throwing the torpedo only 30 or 40 feet, throw it 500 or 600 yards? There certainly would be greater chance of hitting, and, moreover, the expense of each particular torpedo would be greatly reduced, the rapidity of fire increased, and the number of torpedoes which could be carried on board ship would likewise be greatly increased.

"At the request of the above-mentioned

gentleman I took the matter up, and on the 30th day of the following May I filed British patent No. 6591 (1885). The drawings in this patent cannot, however, be considered as working drawings. They only show the principle on which the system was intended to work. The torpedo-thrower was in reality a very large gun with thin walls, the bore being about 24 inches. The diameter of the powder chamber was considerably less than the bore of the gun, and the powder was arranged in successive charges, the first to be ignited being very slow burning, and the last quick burning. By this means I was able to have a low initial pressure, and as the torpedo moved along the bore, the powder burnt faster and faster, maintaining a fairly high pressure to the end of the tube. It was intended to sink the ship by dropping these large torpedoes into the water in close proximity to the ship, and in order to obtain delayed action, the striker of the fuze was placed at a long distance from the primer and the detonating charge. A model of this gun was made, and successfully fired. When, however, we brought the matter before the English Naval Authorities, we found that there was a great prejudice against throwing large aerial torpedoes by the action of an explosive. It was believed by many that the explosion of the initial charge in the chamber of the gun might cause a certain vibratory wave to pass through the metal of the torpedo, and that in consequence of this vibration the bursting-charge might be detonated through sympathy. However, we prepared very large and perfect drawings of a cruiser armed with these guns, and it is interesting to note that the cruiser was very much like the cruisers of to-day, having a speed of 22 knots an hour, which was much higher than any had attained up to that time. The hull of the ship was designed by Sir William Pearce, the engine and machinery by Bryce Douglas, and the armament by myself. Drawings of this ship were brought before the notice of the United States Naval Attaché in London at the time, and I think a set of the drawings was also forwarded to Washington.

" Finding there was so much opposition to throwing aerial torpedoes by the action of powder, I decided to change the system and to use compressed air. But air guns had already been experimented with, and it was found that in order to get anything like a fair velocity, it was necessary to have the barrel of very great length, and, on account of this great length of barrel, it was said that even if accurate aim was taken at the instant of firing, the ship would always move enough during the time that the torpedo was in the bore to throw it off the target. To obviate this trouble, and also the extremely high pressure of air which was necessary, I mixed with my air a small percentage of gasolene. I then had an explosive mixture something like that which is employed in a gas engine, and the gun was arranged in such a manner that when the trigger was pulled the projectile was started in its flight by the action of cold compressed gas and air. However, when the projectile had traversed about one or two calibres of its length, it uncovered the mouth of a small tube, when the pressure pushed a small igniting cartridge backwards against the firing pin which ignited the gas and the air. The result was that while the projectile was still in flight the gas and air exploded, increasing the pressure about sixfold, and producing a high pressure which continued up to the muzzle of the gun.

"In the Zalinski gun, the initial pressure is about 3000 pounds to the square inch, and the report is very feeble, showing that the pressure is greatly diminished before the projectile leaves the muzzle of the gun. In my system I only employ 1000 pounds pressure to the square inch, but the report from my gun is quite as loud as with a powder gun, showing that the final pressure is very high indeed. I think this is the first system of fire-arms ever made in which the final pressure is higher than the initial. By this arrangement I was able to greatly reduce the length of the barrel, and if a torpedo gun not using powder as a propellant had been required, this would have been exactly what was needed.

"The drawings in the patent specification give a fair idea of the construction of this arm. It will be observed that a delayed action fuze is employed, and that the detonating charge is placed at a considerable distance to the rear-ward of the torpedo—that is, it is arranged in such a manner that if the detonating charge goes off prematurely it does not ignite the main charge. However, when the projectile strikes, and its velocity is reduced, the detonating charge travels forward when it comes in contact with the firing pin, and goes off with sufficient violence to rupture the metal and communicate flame to the bursting-charge. This arrangement of fuze appears to me to be the basis on which all delayed action fuzes must necessarily be constructed.

"It was originally intended that ships armed with these large guns for throwing aerial torpedoes should be fought 'head on,' and that they should be protected by an elliptical turret. See my British patent No. 1166, January 17th, 1895.

"It will be observed from the foregoing that I intended to use a torpedo gun of a very large bore, that the projectile which carried the high explosives was in the first instance propelled by powder having a progressive action, that the fuze and detonating charge were placed at a considerable distance from the bursting-charge, which gave a delayed action, and at the same time removed all danger arising from the premature explosion of the detonating charge of the fuze."

Smokeless Powder

"In 1886, naval and military men in England began to discuss the question of a smokeless powder. It was admitted on all hands that a smokeless powder was very desirable indeed, but as far as I know nothing had been done with the view of developing such a powder in England. It was said that the French were discussing the same question, and this was all that was known about it.

"However, my experimental work on the big gun for throwing aerial torpedoes made it desirable that we should have some form of high explosive which could be shot from large guns, and it was proposed to produce such an explosive from nitro-glycerine and soluble gun-cotton, the last named not being considered a high explosive. Nitro-gelatine was already in the market, and extensive experiments had taken place at Shoeburyness with this material, when it was found that about 1 per cent. of the projectiles charged with this substance detonated in the gun. It was believed, however, by myself as well as by my assistant—a very clever man indeed, who knew all about high explosives—that if a still larger percentage of insoluble gun-cotton was employed, a perfectly safe compound might be made, especially so as the velocities that we intended to employ were not high. However, it appeared to me that in any case we should have to do away with all air bubbles so as to prevent the development of heat due to the compression of air. An apparatus was accordingly made in the winter of 1886-7 for removing the air bubbles and consolidating the mass. The apparatus consisted of a press for compressing the compound through holes, and spinning it into threads into a vacuum. Then it was proposed to re-compress the material while in a vacuum, and thus get rid of all the air bubbles. However, we only went so far as to spin it through holes. As the stuff was very thick and hard, it took a considerable degree of pressure to force it through the holes, in fact it was so hard that it was frequently necessary to warm it in order to make it pass the holes at all. In this way we formed threads of nitro-glycerine and a special kind of gun-cotton which had the exact diameter and appearance of the British cordite of to-day. My assistant, Mr MacRoberts, who was superintendent of Nobel's Works in Scotland, believed that any degree of slow burning might be obtained by properly regulating the quantity of gun-cotton employed. This process, and the apparatus for making the cords, were patented by me in England. See my British patent No. 2628, February 19th, 1887, in conformity with which, it is believed, the first-known cordite was produced.

"About the same time that this was patented, I was called upon to fire a Maxim gun at Hythe in the presence of Lord Wolseley and his staff. They all admitted that they had never seen such excellent shooting before. Everything went off without a hitch, and every projectile hit the target. However, at the end of the firing, Lord Wolseley approached me and said: 'Mr Maxim, your gun is splendid. I have never seen such good shooting before in my life, but it is no good unless you have smokeless powder. With your system smokeless powder is a *sine qua non*.'

"On my return to London, therefore, I took the matter up, and upon making enquiries I found that the cordite made by my original process in Scotland would not be acceptable on account of its containing nitro-glycerine, and this, notwithstanding that my assistant, Mr MacRoberts, believed that it would answer perfectly. Finding that the prejudice was so strong against nitro-glycerine, I commenced, in the autumn of 1888, to make a smokeless powder with a gun-cotton basis, and containing no nitro-glycerine at all. My British patent No. 16213, November 8th, 1888, described a gun-cotton powder modified with paraffin wax or resinous matter.

"As the experiments went on it occurred to me that the compound would be improved by the addition of nitro-glycerine, and I believed that if such a powder worked well, it would be taken up by the Government. So on December 20th, 1888, I filed British patent No. 18663 for a smokeless powder, consisting of gun-cotton, nitro-glycerine, and paraffin wax; nitro-gelatine being also mentioned in this patent.

"This was followed up by another patent, filed on March 14th, 1889, No. 4477, in which a compound containing nitro-glycerine, gun-cotton, and castor oil or other suitable oil was described and claimed.

"Fourteen days after filing my patent, Sir Frederick Abel and Professor Dewar filed their application for cordite, and, curiously enough, their application was almost identical with mine, even to the phraseology employed.

"In 1888 Nobel applied for a patent on a smokeless powder consisting of di-nitro-cellulose —that is, collodion cotton—dissolved in nitro-glycerine, and this led to the great cordite case, 'Nobel versus the Government.' Nobel sued the Government for infringement of patent, but it was shown that Nobel's patent was really not connected with a gun-cotton powder at all. It was decided that the material employed by him did not come under the head of gun-cotton, in fact, it was shown in evidence that the patent warned one off from the use of true gun-cotton, and explicitly stipulated that it should be a soluble form of nitrated cotton: consequently the Government had not infringed. Nobel, however, sought to show that his low nitrated cotton always contained a certain percentage of highly nitrated cotton, which would come under the head of gun-cotton, and that consequently the Government had infringed. But Sir Richard Webster, at that time Attorney-General, and afterwards Lord Alverstone, Lord Chief Justice, repeatedly asserted that Hiram Maxim was the first man to make a powder consisting of nitro-glycerine and true gun-cotton. Sir Richard Webster said: 'Nobel sought to tame nitro-glycerine by mixing it with a sluggish explosive—di-nitro-cellulose. Hiram Maxim tamed nitro-glycerine by mixing with it another high explosive. He made the violence of one wipe out the violence of the other.'

"This was proved up to the hilt, and Nobel lost his case. But the Government, in order to beat Nobel, had to refer to my patent, consequently they were liable to be proceeded against by us, and we commenced proceedings against them. However, it is said that no one ever wins a case against the Government. They admitted that their compound contained all the constituents that mine did, but that mine was essentially a gun-cotton mixture, for the reason that it contained more than 50 per cent. of gun-cotton, and that theirs was essentially a nitro-glycerine mixture because it contained more than 50 per cent. of nitro-glycerine. They admitted that I claimed castor oil, or other suitable oil, and it was shown that they employed oil in their mixture. But they asserted that mine was an oil, and that theirs was a hydrocarbon, the actual material that they employed being common cylinder oil, such as is used for lubricating the cylinders of gas engines. They brought many experts to show that this thick petroleum was not an oil but a hydrocarbon, and curiously enough, every man who testified in their favour had either written a book or delivered a lecture in which the same material had been referred to over and over again as an oil. Still, the Judge decided that they had not infringed our patent.[1]

[1] The Maxim cordite case is referred to editorially in the *Engineer* of 1897, February 12th, page 169; February 19th, page 195; March 5th, page 241; and March 12th, page 270. Hiram Maxim claimed that his patent, No. 4477, of March 14th, 1889, had been infringed by the manufacture of cordite at the Government manufactories.

The action was entitled " The Maxim-Nordenfelt Guns and Ammunition Company, Limited, and Hiram Stevens Maxim *v.* Anderson," Sir William Anderson, Director-General of Ordnance Factories at Woolwich, representing the British Government. The case was opened by Mr John Fletcher Moulton, Q.C., and his associates were Mr Roger Wallace, Q.C., Mr A. J. Walter, and Mr Cassel. For the defendant, "I secured other patents on smokeless powder. See my British patents Nos. 680, 1951, and 15,483, issued in 1890. All the early powders made by me were in grains, rods or tubes. However, on September 21st, 1894, I filed British patent No. 17,994 for powder having multiple perforations. This was the first patent ever granted showing multiple perforations, also long sticks of powder with internal cavities, and arranged in such a manner that the fire could get in at the sides of the stick instead of at the ends. Some two years after this patent

appeared the Attorney-General (Sir Richard Webster, Q.C.), the Solicitor-General (Sir Robert Finlay, Q.C.), Mr Haldane, Q.C., Mr Ingle Joyce, and Mr H. Sutton.

In this connection, another published account states that "compassing Mr Maxim was a great cloud of witnesses, testifying to all conceivable things," also that, "the evidence on the plaintiff's side was sufficiently elaborate, but it faded into insignificance when compared with the serried battalion of great, wise, and eminent persons pressed into the service of the Government."

Judgment for the Government was given by Mr Justice Wright on Tuesday, March 4th, 1897, and an Appeal was dismissed, with costs, during July of the same year, as will be seen by reference to the *Times* Law Reports, vol. xiii., 1896–1897, pages 262 and 510.

The main ground of the decision against the patent was that it made castor oil one of the ingredients of the powder. The Government used in lieu of this a hydrocarbon, and the Courts held that this was not an oil in the same sense as castor oil, which was a vegetable oil, and therefore of a different chemical structure from a mineral oil, such as the mineral jelly which was used in the manufacture of cordite.

had been granted, a certain individual came to England and wished to sell a patent to our Company for multiple perforated powder, which he claimed as being superior to all other forms of powder. His attention was, however, called to the fact that the patent already belonged to the Company, and that there was nothing in his American patent which had not already been shown in the English patent bearing a much earlier date. But this part is historical.

"As to the action of smokeless powder, I quote the following from a letter I wrote to a Government official a long time ago. These facts are of value because they have all been demonstrated by actual experiment:

"'When cordite first made its appearance, it was the opinion of some of our very cleverest artillerists that it could not be detonated. I found, however, that every form of smokeless powder could be readily detonated by placing it in an ordinary tin can and setting it off with a small charge of nitro-gelatine. The same may be accomplished, but not with so great a degree of certainty, with a strong fulminating cap. When smokeless powder is burnt in the open, it burns with a great degree of slowness. Some forms of smokeless powder will not burn in an atmosphere of their own gases, except under a high pressure. Pressure is a very important factor in the burning of powders. The rate of combustion may be said to increase in geometrical progression as the pressure is increased. Two pieces of burning powder cannot be brought into actual contact. As two pieces of burning powder approach each other, the pressure between them is increased, and as rapidity of burning will increase *ad infinitum* as the pressure is increased, it follows that the pressure of the gases will always be sufficiently great to prevent the two pieces of burning powder being brought into actual contact. It therefore follows that when the charge is fired, the grains or sticks automatically space themselves in the chamber of the arm, becoming just as distant neighbours as space will admit. When a charge of smokeless powder is employed in a large gun, upon igniting it, all the grains separate from each other, and combustion goes on increasing in energy and rapidity as the pressure increases; every increase of pressure increases the temperature, and the temperature in its turn increases the rapidity of burning, which again reacts upon the temperature and pressure. We, therefore, have action and reaction following each other very rapidly, each one exceeding the other, until the rapidity of burning becomes very great indeed. Suppose now that the projectile was not allowed to move, and suppose that the volume of the chamber should be constant, the rapidity of burning would increase until the whole charge was consumed, the last two-thirds of the charge would go off quite as rapidly as nitro-glycerine would. What is it then that prevents this occurring every time a gun is fired? There are two things. One is the movement of the projectile forward, which not only converts a certain portion of the heat energy into dynamic energy, but also gives more room in the chamber; at the same time the sticks or grains of powder are becoming smaller, and the surface on which the flame works is reduced.

We might consider that we have two agencies in a gun which tend to exalt and increase the rapidity of burning, viz., the pressure acting upon the rate of combustion, and the combustion upon the pressure; and two agencies which operate in a reverse direction, viz., the movement of the projectile from the burning charge, and the diminution of the burning surface of the powder. The two last working together are always sufficient to prevent the detonation in the gun. Some nations have, however, employed large flat flakes or strips of powder; others have manufactured the powder into tubes, and these give an approximately uniform burning surface until the complete charge is consumed. In such powders we only have one agency to prevent the great rise of pressure in the gun, which might eventuate in a disastrous explosion, but as a rule it is quite sufficient to prevent such a catastrophe.

" ' Before I understood this question fully, I patented a certain form of powder, in which the burning surface was increased instead of diminished; I accomplished this by many fine longitudinal perforations in the sticks of powder. The fire entered these small holes and burnt them larger. It therefore followed that as the powder was consumed, the burning surface was increased. This was a very interesting powder, and seemed to give a very simple and effective means of producing high pressures throughout the whole length of the bore of the gun, with only a moderate initial pressure. Let us see how this powder behaved. When we came to try it, it produced excellent results up to a certain point, but when anything like a full charge was employed, we found it very erratic indeed. It was liable to produce extremely high pressures. Although this powder was patented by me in England ahead of all the patents in the world, I did not patent it in any other countries, as it was not satisfactory.

"'Density of Loading

"'The density of loading is also a very interesting subject. If smokeless powder was formed into perfect spheres, the grains would grow smaller in all directions as the powder was consumed. With such a powder the density of loading could be much greater than with the flat or tubular variety. The next best thing, as far as density of loading is concerned, is the employment of solid sticks of powder. These give great evenness of results with very little liability of erratic action. With tubes or flat pieces, the density of loading has to be less, otherwise very uneven results would be obtained, and the pressure might mount so high as to destroy the arm. The density of loading has to be much less with the multiple perforated variety than with any other powder known. In the United States of America a 10-inch gun was fired with very nearly a full charge of this powder, and produced excellent results, but, upon adding a very slight fraction more to the charge, the rapidity of burning was increased so much that the projectile was unable to move fast enough in the bore of the gun to relieve the pressure. A very violent and disruptive explosion followed, which not only demolished the gun but destroyed the bomb proof, and killed and wounded the detachment. I have known several cases where powder with a single perforation has given very good results on the Continent, but, whenever the charge was increased, the pressure became exceedingly high and irregular. I think we may assume from all the data at hand that we must not go further in powder than the flat or tubular variety. It is safe to use a powder in which the burning surface remains constant, but it is not safe to use one in which the burning surface is increased to any considerable extent.

"'Effect of Heat

"'In hot climates, especially if the gun has fired a considerable number of rounds, it may happen that the charge remains a few minutes in the gun before the order to fire is given, so that at the instant of firing the charge may actually have reached a temperature of 150° F. It is, therefore, very essential that we should employ in large guns powders that are least affected by change of temperature, not only as regards safety, but also as regards accuracy of firing. It has been found by experiment that the solid sticks of powder are the least affected by change of temperature, everything else being equal, and that the tubular and flat varieties rank next to the solid sticks; any slight change of temperature, however, affects in a very marked degree multiple perforated powder. But multiple perforated powder can be made which will give a practically constant burning surface the same as tubes, and it has the advantage of being in larger sticks, and therefore stiffer.

"'For smokeless powder, gun-cotton is all that could be asked for, in every particular except one. It is stable, very powerful, smokeless, doesn't injure the metallic case, and is not too hygroscopic, but it explodes too quickly—this is its one fault. I think that its rapidity of exploding could be modified in a small degree, and it requires only a small degree to make it all right (it should be quicker than gunpowder) in the following manner :—Gun-cotton can be dissolved in ether the same as sugar can be in water. When dissolved, it forms a sticky varnish ; when it dries, it dries very quickly. The varnish in its dry state is solid gun-cotton, and is explosive. Now, suppose that gun-cotton be ground fine into a paper pulp, and then treated slightly and only sufficiently to be sticky, not dissolved ; this could be done by sprinkling or only slightly wetting the cotton with the ether, or the cotton could be slightly warmed, and steamed with the vapours of ether. When the whole mass has become sufficiently sticky, it could be pressed into small thick sheets, say, 6 in. square and $\frac{1}{16}$ in. thick ; the press should be a very strong one, and the pressure on the cotton very high, higher than any it would ever encounter in the gun ; a moderate heat might be used while the cotton was in the press. Perhaps the success or non-success of the experiment might depend on the degree of pressure employed. I believe that at least 20 tons to the square inch should be employed, and 40 might be better. Having obtained our sheets of solidified cotton, we should then proceed to cut them up, so as to form small cakes $\frac{1}{16}$ in. square. These could have their corners rounded by rumbling. If, after this treatment, we should find that the powder or cotton was still too quick, then I should try again by mixing some other substances with the cotton which would have a tendency to slow up the rate of combustion. The rationale is this : Gun-cotton, when used in a gun, goes off too suddenly, because the high pressure set up ignites the whole mass instantly by compression. If it were in lumps or grains of some size, in such a state of compression that no pressure in the gun could compress it more, then it could only burn from the outside of the grains, and the time, although quick, would be a measurable one, and long enough to allow the projectile time to move before the whole mass should be in a state of ignition. A slight mixture of mineral wax or resinous matter, or hydrocarbons, combined with some oxygen-bearing salt, like nitrate of potash or soda or chlorate of potash, might facilitate solidification, and slow up the rate of burning.' "

Smokeless and Other Powders

For additional information regarding powders consult the chapter on Explosives, also the following articles in *Engineering*:

February 7th, 1890, p. 146—Editorial Report on Lecture of Sir Frederick Abel before the Royal Institution.

April 2nd, 1897, p. 451—Hiram Maxim's apparatus for Testing Smokeless Powders; illustrated and fully described.

March 8th, 1898, pp. 297–301—" Modern Artillery," a very interesting article by Lieut. A. T. Dawson, late R.N., wherein he discusses powders, automatic small arms, heavy types of automatic guns, etc.

October 28th, 1904—Review of the paper read by Capt. Charles L. Ames, U.S.A., on the first day of meeting of Civil Engineers' Congress, tracing the development of smokeless powder from the earliest times, giving due credit to the work of Abel, Dewar, Nobel and others, and also dealing with fuzes, primers, and projectiles generally.

Issues of July 10th, Sept. 18th, Sept. 25th, and Oct. 30th, 1908.

May 31st, 1912, p. 754—Smokeless Powders and their behaviour under the ultra violet rays.

Consult likewise the following periodicals :—

Science, N.S. vol. xiv., page 767.

Nation, vol. l., page 388.

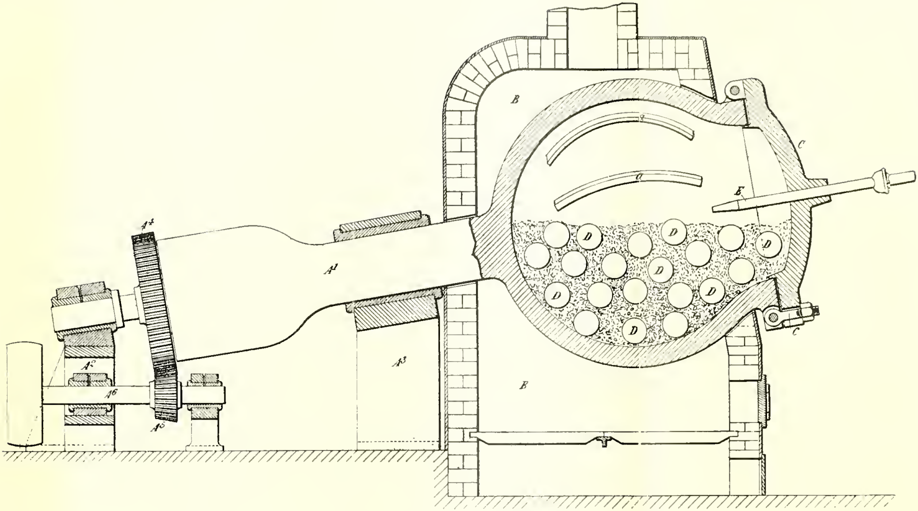
United Service Magazine, vol. iv., pages 66, 67, 396, 518, and vol. vii., page 1239.

Cassier's Magazine, vol. xv., page 115.

Appleton's Magazine, vol. viii., page 580.

When alluding in one of his letters to an American experimenter on an extremely slow burning gunpowder called "Motorite," Sir Hiram Maxim said: "He proposed to enclose this in a strong steel receptacle and ignite it, and then run a motor similar to a steam-engine with the gases under a very high pressure, the engine being made strong enough to stand the pressure. When we obtain power from a steam-engine we buy the coal and put it into the furnace, but the oxygen to consume it we do not have to pay for. In gunpowder 75 per cent. of the weight is due to the nitrate of potash, which is the oxygen-bearing salt, and this is by far the most expensive part of the powder. In running a motor-car we pay for the carbon and the hydrogen. We know that the carbon will develop 14,000 B.T.U. for each pound consumed and that the hydrogen will develop 60,000 B.T.U. per pound, but it requires an enormous quantity of oxygen to develop this heat. If we had to purchase the oxygen it would be very expensive to run a motor-car, but as we get the oxygen absolutely free from the surrounding atmosphere the expense of running is very low."

The experimenter did not, however, know this, and after expending much money in the attempt to develop the so-called "Motorite," it had to be abandoned altogether.



PATENT No. 22812. NOVEMBER 28, 1895
MAXIM'S PROCESS OF EXTRACTING GOLD FROM REFRACTORY AURIFEROUS ORES

EXPLOSIVES

A VERY careful examination of the printed indexes of grantees of British patents for inventions concerning explosives containing either gun-cotton, gun-cotton and nitro-glycerine, or gun-cotton, nitro-glycerine and castor oil, which was instituted from the year 1865, shows the following early patents granted to Sir Hiram Maxim, viz.:

No.	6,926	dated	8th June	1885
,,	2,628	,,	19th February	1887
,,	16,213	,,	8th November	1888
,,	18,663	,,	20th December	1888
,,	4,477	,,	14th March	1889

During 1903, Sir Hiram's attention having been called to the disastrous explosion of a large and valuable mortar in the United States, the cause of which was in great measure attributed to the development of strong wave motion, he wrote to a friend as follows:

"There is something in this. Wave action may interfere with the accuracy of fire, it may increase or diminish the velocities, and it always causes the maximum pressure to be increased, but never to the extent of bursting a well-made gun. In order to prevent wave action in long cartridges, and in order to have the sticks very large and strong so as to remain firmly in their place, I patented long sticks of powder with internal cavities and means for the fire entering at the sides instead of at the end of the sticks, thus effectually prevented all wave action; but as solid sticks of powder were cheaper and already in the service, and as we had obtained excellent results with them, we never succeeded in introducing our large sticks with internal cavities arranged in such a manner that the flame could enter the side of the stick. The first long sticks of large powder actually used in a gun were made by me at Crayford in 1896-1897, and were tested at our Swanley Range. The experiments were conducted with a 4.7 inch gun. I first found out how thick a stick of Government cordite would be consumed in this gun. If I remember rightly the sticks were slightly less than $\frac{1}{4}$ inch in diameter and we found that these were reduced to about the size of a horse hair. I then took some very large sticks of exactly the same kind of composition, and, after having made a machine, I perforated them so that the distance between the holes was equal to the diameter of the smaller sticks. The perforation was performed in a machine having a large number of steel needles, which were pressed into the powder from both sides. Upon commencing our experiments we found that, with half charges, the results were identical. With those obtained when employing the smaller powder with $\frac{3}{4}$ charges, the multiple perforated did somewhat better and gave fairly even results. Upon slightly increasing the $\frac{3}{4}$ charge the pressure mounted much higher than it should have done and was very irregular, no two results being alike. When further increasing the charge only to the extent of a few ounces, this pressure suddenly mounted to 22 tons to the square inch, which was looked upon as a dangerous pressure. The next day we tried the heat test. We took the ordinary small powder about $\frac{1}{4}$ inch in diameter and heated it up to about 150° F. and fired it with only a slight increase in the pressure. But a $\frac{3}{4}$ charge of the multiple perforated produced a very high pressure—I think something like 25 tons. I will say that the gun which I used on that occasion was of very great strength, perhaps stronger than you would be prepared to believe.

These experiments, which taught us that the multiple perforated powder was extremely dangerous, took place long before any powder was made in the States with transverse perforations. We have fired many hundreds, and even thousands, of rounds of ammunition with our field guns, and we have, on the whole, obtained very good results. With ballastite the results were even—we never had excessive pressure. We made a field gun for a foreign nation and the powder that they gave us for it had a single perforation. The ratio of burning was about the same as it would be with ribbons of powder, that is, practically a uniform burning surface. This powder gave better ballistic effects than we had ever obtained before with the same weight of powder. The velocities were high and the pressures abnormally low. We fired some hundreds of rounds with most excellent results, and every one appeared highly satisfied. However, when we came to the final trials, and while the gun was still cold, a cartridge, which had been loaded exactly like all the others, produced an extremely high pressure—so very high, in fact, that the gun was ruined, although it did not burst. A quantity of the so-called Maximite multiple perforated powder appears to have been sent over to the Armstrongs when Sir Andrew Noble lectured at the Royal Institution. He showed a block of this powder, holding it up between his thumb and finger, and, as has been already remarked, he said that it was an interesting powder but liable to produce extremely high pressures. As I stated before, I was the first to patent multiple perforated powder. I discussed it years before I patented it, and still I did not think enough of it to patent it in any country except England.

"Now, as to employing picric acid. Many years ago, I think it was in 1885 or 1886, Eugène Turpin commenced experiments in France with picric acid. He did not succeed at first, but in the meantime I had taken out a patent myself (in 1883 or 1884, I think) for modifying the violence of high explosives by mixing them with heavy hydrocarbons. Turpin took advantage of this, and by mixing only a slight amount of thick and viscid petroleum with picric acid he succeeded in so reducing its sensitiveness that it could be shot through an armour plate without detonating by impact. At that time I was a great deal in France, and lunched very often with the experimental staff. I remember distinctly what they said on these various occasions. They claimed that they had a totally new explosive. They said that if you placed it on an anvil and struck it with a sledge-hammer it would not go off, that it might be placed in an iron pot and boiled away without taking fire, that a mass of it might be safely stirred up with a white-hot iron, that they had thrown large lumps of it into a white-hot furnace and it would not even then explode, also that it would pass through an armour plate with perfect safety. They further stated that when it was confined in a strong receptacle and set off with a strong detonating fuse, it went off very violently, the disruptive effects being greater than with dynamite. One day, while lunching with the officers, a gentleman came in with a very large and expensive fur collar. They said he had lately made a lot of money. I asked how he had made it, and they told me it was through his having gone to England and purchased there for the French Government every kilogramme of carbolic acid that could be obtained. It then occurred to me that this very wonderful explosive might be made out of carbolic acid, *i.e.* tri-nitro-phenol or picric acid. On returning to England I at once obtained a quantity of picric acid and found it would stand all the tests boasted of by the French officers, except being struck with a sledge-hammer. I then mixed with it something like 5 or 10 per cent. of vaseline and paraffin wax and found that it stood every test. I made many experiments with it. I loaded a common shot-gun with black powder and then put this picric acid compound on top of it and shot the picric acid through a one-inch spruce-board. Later on I modified it, and reduced its melting point by intimately mixing with it a small percentage of di-nitro-benzol, but I went no further than this, because I learned that Sir Frederick Abel and Professor Dewar had found out the secret of the French melinite about a month ahead of me. However, I must say I felt rather proud that I had discovered their secret, and I was much gratified to find that the two greatest chemists on explosives in England had done exactly the same thing as I had done myself.

"Picric acid is a very peculiar, a truly wonderful, explosive. It was originally made from indigo, and was extensively employed in the Arts as a dyeing material for about a hundred years before its true character as a high explosive was even suspected by scientific men. Picric acid crystallizes in thin scales, and stains all animal substances a deep yellow.

"The first picric acid was, as already stated, made from indigo, but at the present time, like a great many other nitro bodies, it is made from the by-products resulting from the distillation of coal gas. I think we may consider it as the first of the aniline dyes.

" When carbolic acid (phenol) is dropped into a strong mixture of sulphuric and nitric acids, the hydrogen is displaced by what are known as 'nitrogen groups'—that is, nitrogen and oxygen grouped together—and the water resulting from this decomposition is seized on by the strong sulphuric acid which is present in the solution. When the acid is very strong, and the process goes on slowly, tri-nitro-phenol is produced, known in the Arts as picric acid.

" Previous to 1887, picric acid was not considered an explosive at all, and there was no law in England which prevented its being handled and carried in the same manner as other chemicals which were not explosives. However, in 1887, a very disastrous explosion took place at Cornbrook, near Manchester, England. A full account of this explosion will be found in Colonel Majendie's special 'Report to the Right Hon. the Secretary of State for the Home Department.' On this occasion picric acid was stored in close proximity to chemicals that were known to be high explosives, and when these went off the picric acid went off at the same time, producing almost unheard-of results. At first the violence of the explosion could not be accounted for, but upon investigation it was shown that picric acid was indeed a high explosive.

"Monsieur Eugène Turpin, a French chemist and engineer, who has already been named, was the first to take advantage of this new discovery. It appears that he commenced experiments at once, and very early demonstrated that when pure picric acid was confined in a strong steel receptacle under high pressure, it could be set off every time with a proper detonating charge, and that when it did go off the results were something terrific. In many cases the steel receptacle was reduced to fine particles.

"After finding that picric acid was an extremely violent explosive, and that it could be detonated, Turpin commenced experiments with armour-piercing projectiles. He found that picric acid could be shot from large high-power guns with the greatest degree of safety. The shock of the discharge was never sufficient to detonate the charge. However, a much greater shock than the projectile received on striking an armour plate would set off the charge, so that, in the first instances, his projectiles exploded before they passed through the armour plate. This led to further investigation. At that time my British patent for modifying high explosives with paraffin wax had been published, and Turpin, as we have before stated, taking advantage of this, experimented with heavy petroleum, and found that when a very small percentage of a thick and viscid petroleum was mixed with picric acid, its sensitiveness was sufficiently reduced to enable it to stand the shock of passing through an armour plate without being detonated. See description in Eissler's latest handbook on 'Modern High Explosives.'

"Turpin appears to have made many explosives, of which picric acid was always the basis, and one of these was taken up by the French Government and christened 'Melinite.' The composition of the latter was regarded as a secret at first, and the French artillery officers, who had witnessed experiments with this remarkable explosive, were very much impressed. They were never tired of bragging about the marvellous results produced by what they claimed to be a totally new form of high explosive.

"At the time that these experiments were taking place I was also conducting experiments in France, and the men who were experimenting with melinite were also experimenting with a Maxim gun at the same time. I was therefore brought much into contact with these officers, and witnessed a good deal of their boasting. They claimed that France was always ahead in artillery matters, especially in the chemistry relating to artillery, and that they had a high explosive as strong as nitro-glycerine which could be handled with perfect safety. I remember distinctly that they said that it could be thrown into a white-hot furnace without exploding, that a white-hot poker thrust into the mass simply set it on fire, that it might be put into a kettle and completely evaporated by heat without even taking fire, also, as before stated, that if placed on an anvil and struck with a sledge-hammer it would not detonate. Its specific gravity was very high, consequently a very large amount could be loaded into a small space. If set on fire in the open air, even in large masses, it would simply burn away like so much wood, but never explode. They said there was only one way to explode it, and that was to strongly confine it, and set it off with a peculiar form of detonator which they had. They said it was the first really high explosive which could be shot from a large high-power gun with safety, and the only high explosive ever discovered that could be shot through an armour plate without going off by impact. I remember distinctly what they said in regard to the turret defences on the frontier. They said that a plunging shot could be loaded with melinite, and that, so loaded, it would penetrate four metres of masonry, and only explode when it had been brought to a state of rest. They claimed that a few such shells would completely silence the batteries of the largest ironclad, and that France alone knew the secret of this wonderful explosive.

"I continued my experiments, and mixed various other nitro bodies with picric acid. I found that similar nitro bodies, such, for example, as di-nitro-benzol, greatly reduced the melting point, and also made the compound less sensitive, and that the sensitiveness could be reduced to any extent by the addition of only a very small percentage of castor oil, vaseline, or paraffin wax. I also made compounds in which di-nitro-cellulose, tri-nitro-cellulose, and nitro-glycerine were included. When my experiments were finished I brought the matter before the notice of some British naval and military officers, but they told me it would be no use to bring it before the Government, because, they said, they already had a high explosive which filled all the conditions claimed for the French melinite.

"I afterwards learnt that the British Explosives Committee of 1888-89-90 had found out for themselves what the French melinite was, in exactly the same manner that I myself had found it out, but that they were ahead of me by some months. Consequently, there was nothing in my discovery either for me or for my Company, and, curiously enough, I still later ascertained that they commenced their experiments, as I had done, with pure picric acid, that they had found it could be detonated with a blow from a sledge-hammer, and that they had modified it by mixing with it di-nitro-benzol, tri-nitro-napthalene, di-nitro-napthalene, and many other similar bodies. They had also made experiments in which nitro-glycerine was a part of the compound, and had used various forms of oil and grease for reducing its sensitiveness, such, for example, as napthalene, vaseline, paraffin, and similar hydrocarbons. Extensive experiments were made with this modified form of picric acid, and photographs were shown to demonstrate the violence of the explosions.

The experiments were conducted at Lydd; the new material (modified picric acid) was called Lyddite, and became the high explosive of the British Service.

"However, the British Government have since found by actual experiment that, when picric acid is sufficiently modified to stand the shock of striking an armour plate without being detonated, the difficulty in detonating it becomes greatly increased, in fact, one might say, almost impossible with anything except very large shells, where a very large detonating charge may be employed. The 4.7 inch lyddite projectiles employed in the South African War were charged with pure picric acid, and even with this, 75 per cent. of the shells failed altogether to go off, whilst the greater number of those that did go off simply burst the shells and threw the unconsumed picric acid out in the form of dust.

"Picric acid, even in its modified state, may be readily set off with a very large detonator charged with fulminate of mercury, but the use of fulminate of mercury is forbidden in the English Service except in primers and in the fuzes of very small projectiles.

"Picric acid forms the basis of a great number of 'ites.' In the 'British Service

Dictionary of Explosives' thirty-nine explosives are shown in which picric acid is an important constituent. In these 'ites,' picric acid is modified by the addition of various substances, among which I would mention :

Tar	Nitric acid
Nitrate of soda	Nitro-glycerine
Tri-nitro-toluene	Asbestos
Sawdust	Nitro-benzol
Litharge	Di-nitro-benzol
Prussian blue	Drying oils
Nitrates	Nitro-cellulose
Prussiate of potash	Nitro bodies
Phosphorus	Tri-nitro cresylic acid
Collodion	Olive oil
Glycerine	Gun-cotton
Picrate of ammonia	Sugar
Charcoal	Oils (various)
Carbonate of ammonia	Hydrocarbons
Sulphur	and
Chlorate of potash	Resinous matter.

"When a picric acid compound is loaded into a large projectile, the set-back at the instant of firing is about 10,000 times the weight of the charge, or, say, about 10,000 pounds pressure for every 14 inches in the length of the charge. Under this enormous pressure the material flows like water, and all the air bubbles find themselves consolidated at the forward point of the charge. When the projectile strikes an armour plate, the whole charge is set forward with a force which is only limited to the strength of the steel, and whatever air bubbles there may be become suddenly violently compressed, which, of course, develops a high temperature at the particular point where the pressure is greatest. If pure picric acid is employed the heat and pressure are sufficient to detonate the charge. Although pure picric acid may be put into a kettle and boiled away over a fire without being ignited, still the same temperature which is required to volatilize it will quickly ignite it if the heat is brought suddenly into action, as, for example, if confined picric acid is dropped on to a hot plate, only sufficiently hot to evaporate picric acid, it will always set it on fire. I think Professor Dewar was the first to discover this, and it is this peculiarity that causes pure picric acid to be detonated when it strikes an armour plate. However, by mixing, say, 10 per cent. of di-nitro-benzol with picric acid, the melting point is greatly reduced, so that the compound easily melts in hot water. With such a charge the high temperature developed by the compressed air spends its force in melting the mass instead of in detonating the charge. When, however, paraffin wax or vaseline is present, even in small quantities, the liability to go off by impact is very greatly reduced, because the first manifestation of heat is absorbed in melting and evaporating the paraffin wax or vaseline. Moreover, the greasy nature of these substances prevents the attrition between the particles of acid and the walls of the projectile.

"I have experimented extensively with a great number of nitro bodies, such as tri-nitro-toluene, tri-nitro-cresol, tri-nitro-napthalene, tri-nitro-mannite, di-nitro-napthalene, di-nitro-benzol, nitro-benzol, and so on, but my experiments have demonstrated that none of these substances have any advantage over di-nitro-benzol, which, in combination with about 2 per cent. vaseline, is an excellent compound to modify the sensitiveness of picric acid. That is, eight or ten parts of di-nitro-benzol and two parts of vaseline are generally sufficient to reduce the sensitiveness of picric acid sufficiently to enable it to pass through an armour plate without being detonated. Even with only 1 per cent. of vaseline added to picric acid, a very perceptible increase of its insensitiveness is apparent.

"I have found by experiment that it is better that the substances should be ground together under an Edge mill instead of being melted together, and that in loading the shell they should only be softened by heat, and then cooled as quickly as possible. This prevents the picric acid from crystallizing and separating from the other materials.

"In order to detonate a charge of picric acid which has passed through an armour plate, it is necessary to employ a detonator which will at least produce a local shock equal to the shock of striking an armour plate, and at the same time produce a high pressure and temperature. When the projectile strikes the armour plate the shock is very great indeed, but the amount of heat developed is extremely small, that is, if the projectile is properly charged. It therefore becomes possible to set off a charge by shock and high temperature, such as one finds in the explosion of a strong explosive like smokeless powder, which cannot be set off by shock alone. However, if the picric acid is modified too much it will be found impossible to set it off at all, no matter what kind of a detonating charge is employed. On the other hand, if it is not modified sufficiently it will be detonated by the shock of striking the armour plate.

"There is no way in which one can legally conduct experiments in England with high explosives. It is the law that no explosive can be employed which has not been tested and approved of by the Government, and as an explosive cannot be made or tested without experiment, it follows that it cannot be made at all, unless one evades the law and takes the chances of being heavily fined. Some years ago, on completing an order for semi-automatic guns for a foreign Government, we found that the cartridges (3-pdrs.) had been purchased in France, but as it was necessary to test all automatic guns with the actual cartridge to be employed, and as it was illegal to import large loaded cartridges into England, we asked to be supplied with some of the powder so that we could conduct experiments on our own premises to ascertain if the new powder would work the mechanism of the arm. The material sent over to us looked like the bark of a tree, very rough and irregular, but it had produced excellent results in France. Upon applying to the British Government for permission to test the gun with this powder, the reply came that it was a picric acid powder, and picric acid was an illegal compound, not to be employed in England. We then asked permission for the foreigners to fire their own gun, all British subjects to be kept out of range, but even this was denied. The Frenchman who brought the powder over piled a considerable quantity of it upon our premises, and set fire to it, when it burnt away like so much pitch pine. However, the Government absolutely refused to allow us to fire a single charge of this powder in our gun, simply because it contained picric acid, and picric acid, as an explosive to be used in fire-arms had not, up to that time, been submitted to the Government and been duly approved of by them.

"The gun-cotton which was first employed in Europe as an explosive was badly made, and consequently very unstable. It was liable on the least provocation to give off nitrous fumes, and to explode spontaneously, and it was this peculiarity that gave it a 'black eye' in Europe for many years.

"When, however, the matter was taken up by Baron Von Lenk, he discovered that the accidental explosions were due to the imperfect manner in which the gun-cotton had been nitrated and then freed from its acid. Later on, Sir Frederick Abel, the cleverest chemist on explosives that we have ever had in England, took the matter up, and devised a process for the manufacturing, washing, and pulping of gun-cotton, which produced an article of very great stability, an article which could be kept for any length of time in any climate without the least sign of deterioration.

"The question then came up as to whether well-made gun-cotton if set on fire in the open would burn away or would detonate. Sir Frederick Abel demonstrated that when small quantities were ignited in the open air it flared up, producing a very intense flame, but nothing in the form of an explosion. Others believed that, if the mass was large enough, the rapidity of burning might increase until it reached a stage which would correspond with a true explosion, and to test this, I think about a ton of gun-cotton was placed in a field, where Sir Frederick Abel struck a match and touched it off, after which he started to walk away. He had not gone far, however, when the whole mass detonated with terrific effect, producing an immense crater in the earth and knocking down and nearly killing Sir Frederick.

"When English cordite first made its appearance, Sir Andrew Noble expressed it as his opinion that it could not be detonated even under high pressure, much less if set off in the open air. In order to combat that theory, I obtained two large cans made of thin sheet steel, and I put about 100 pounds of smokeless powder in each. I placed the cans about a foot apart, and put a strong detonating charge carrying about two ounces of nitro-gelatine on top of one of them. The result was that both cans detonated with about the same effect as would have been produced by a similar weight of dynamite. A crater 4 feet deep and 12 feet wide was scooped out of hard and compact gravel.

"Shortly after this, the British Government made another experiment at Plumstead Marshes. A large number of tin cans, filled with cordite, were piled up, and a lot of loose cordite placed on top of the pile. This was ignited with a flame, and at first burnt away rather slowly. However, the intensity of the flame rapidly increased, the flame was forced down amongst the mass, and the further it went the more the pressure was increased, until a stage was reached where the pressure was sufficiently great to cause the whole mass to go off instantaneously—that is, a true detonation. The hole scooped in the ground is said to have been 15 feet deep and 24 feet in diameter, and an immense number of windows, within a mile radius, were broken, precisely as was the case in the experiments previously noted.

"Some years ago we made a series of experiments with multiple perforated powder. We obtained a quantity of large sticks of powder having a diameter of about half-an-inch. These were cut the exact length of the charge, and I made a machine which punched a very large number of holes transversely through these sticks, so that the space between the holes was about equal to the diameter of sticks of powder which could be burnt in a 4.7 inch gun. In the first day's trials the powder was used cold, and produced results rather better than could have been produced with smaller sticks not perforated, until a velocity of about 2000 feet per second was obtained. When, however, we attempted to add to this velocity, the pressures became very erratic and irregular. The second day's experiments were conducted with the same kind of powder, which had been slowly heated to a temperature of 100° F. We commenced with increasing charges, and when we had come up to a velocity of about 1800 feet per second, the pressures became very unsteady and irregular, and when we attempted to increase the velocity by the addition of only a small percentage to the weight of the charge, the pressure suddenly mounted to 24 tons to the square inch without any rhyme or reason. It was found that this powder was not reliable, although under certain conditions, where the pressures and velocities were low, it did a little better than solid powder. I would say, however, in connection with this, that these large sticks of powder were not sound, that is, in being pressed through a die it appears that the inside had become flaky—or, as one would say in regard to wood, shaky—and, in drying, there was a distinct series of splits running through the entire length. When we made transverse perforations we practically had powder which was perforated in two directions. The fire was let in at the sides through the perforations, and got into the cracks, burning outwards. This powder was considered unsafe.

"Messrs Armstrong, Whitworth & Company ordered a quantity of multiple perforated cannon powder from the States. This powder was cut into short lengths; the fire entering at the ends of the sticks, and, as is known, Sir Andrew Noble, in lecturing on explosives later on, referred to this powder as a very interesting one but liable to produce extremely high pressures.

"In carrying on some gunnery tests on the continent of Europe, we were supplied with a quantity of powder which had originally been made tubular in form, and which was cut into short lengths or rings. It produced better results than could have been produced with powder in the form of solid sticks, with a fair degree of steadiness in pressure and velocity. Many shots were fired, the results being highly satisfactory. However, in the end, one charge went off with extreme violence, stretching the gun and deforming the mechanism, at the same time producing a jump and a recoil action much stronger than we had ever experienced before. I had 10,000 cartridges sent to me from Germany to test. After firing about 2000 rounds without a single hitch or fault of any kind, one cartridge detonated, and burst the barrel. We continued the experiments, and whilst firing with a new barrel which was quite cold, about the twelfth cartridge detonated, straining the barrel and disabling the mechanism. The cartridge had not been in the barrel a tenth part of a second when it was struck, consequently it could not have been influenced by the heat of the barrel. Moreover, the barrel was comparatively cold at the time. In continuing my firing, I found that four cartridges, out of the 10,000 sent to me to test, detonated. Upon calling the attention of the makers to this, they at first denied that it was a fact, but in the end I think it was decided that by some hook or crook the four primers that had spoilt the guns had received a double charge of fulminate of mercury.

"When the Germans first experimented with a Maxim gun, using black powder cartridges, we repeatedly had our barrels bulge; no matter how strong or well made the barrels that were supplied might be, they nearly always gave out after a few rounds had been fired, the bulge generally taking place about half-way up the bore, and the barrel looking like a snake that had swallowed a toad. As everyone else had failed to make out what the trouble was, the matter was brought before me, and it occurred to me that there could be but one cause for this trouble, and that was that a certain portion of the cartridges had no powder in them at all. Upon calling Mr Nordenfelt's attention to this, he ridiculed the idea altogether. He said that Germany was a first-class nation, where everything was done with the greatest of care, and there was not even the ghost of a chance that a single cartridge should be improperly loaded. However, I went to Germany, and found that the cartridges they had been using were loaded by the soldiers on the field. When a soldier had committed a misdemeanour of any kind, he was set to cleaning, re-sizing and re-loading a certain number of cartridges, and a number of these cartridges were completely without powder.

"When the English adopted the small bore Maxim gun, using smokeless powder, they claimed that after firing 1000 rounds the gun failed to fire altogether on account of lack of energy. I asked them to send me a gun and 15,000 rounds of cartridges, but I specified that the cartridges should be provided with a little pasteboard wad at the base of the projectile. I commenced my experiments by firing regulation cartridges from a regulation barrel, and found that when only 600 rounds had been fired, the energy fell off to such an extent that the gun worked very feebly, and not more than 2 per cent. of the projectiles struck the target, which was only 100 yards distant; the greater number of the projectiles flying off to the right at an angle and all of them producing key holes. I continued firing, and when 1000 rounds had been fired, the gun failed to work from lack of energy. I then made a barrel to exactly fit the cartridges that had been sent, ignoring altogether the lithographed dimensions which had been given me. I then fired 6000 rounds straight off; every shot went through the centre of the target. I returned the remainder of the cartridges to the Government, and the experiments were continued until 22,000 rounds had been fired, when the gun still worked fairly well.

"Shortly after this I was informed that the Government were quite unable to make their Maxim gun work with black ammunition, such as was used in the manœuvres. They said that the gun worked with very great irregularity. They were quite sure that all their cartridges were loaded exactly alike, but sometimes the handle would only jump, sometimes it would go half way over, and then again it would go over with a crash, and with violence that would break the mechanism. It was reported that in some cases the piston arrangement at the end of the barrel, which was employed for working the gun by the force of gas pressure, was destroyed, whilst sometimes the muzzle of the gun was very much enlarged. And all this with cartridges containing very small charges, no bullets, and all loaded exactly alike. I asked them to send me a couple of guns and 5000 rounds of cartridges. I found that the powder consisted of very thin shavings cut from large sticks of cannon powder of the standard cordite composition. Upon firing, I found that the primer was not strong enough to ignite the charge every time, but was quite strong enough to blow it up the barrel. Cordite will not burn in an atmosphere of its own gas except under high pressure, consequently the cordite shavings remained in the barrel until about four or five charges became packed together. Then perhaps one cartridge would go off, on account of the back pressure, and this would ignite the whole mass, when the whole lot would detonate like so much dynamite, destroying the barrel, or wrecking the mechanism—perhaps both. The remedy for this was to provide a gun-cotton powder which could be ignited with greater ease.

"When a certain number of our 37 mm. guns were ordered by the French Government, I was asked to attend the trials, and to fire the gun myself at a target which was at a considerable distance. After firing about 25 rounds, the target became completely obscured with the smoke, notwithstanding that the cartridges were loaded with smokeless powder. I found that in order to ignite the charge with the primers which the French employed, they had placed at the base of each cartridge case a small cotton bag loaded with black powder. The primer ignited the black powder, and the black powder ignited the smokeless powder. On my return to England, I obtained a quantity of canvas, and nitrated it in a peculiar manner. I cut out a lot of round patches, and sent these over to France. They placed them in the base of the projectiles, and thus completely eliminated the smoke nuisance, at the same time ensuring a quick and sure ignition. The French then wanted to know how it was possible that I could take a piece of thick canvas and make it all into tri-nitro-cellulose. They had found, on testing this canvas, that it was practically all tri-nitro-cellulose, and they could not account for it. When they attempted to make it themselves, they always obtained a lot of the di-nitro or the soluble variety, and they asked me for an explanation. Did I nitrate it in a loose and highly divided state before it was woven into canvas—or what? I then informed them that I had soaked my canvas in a solution of nitrate of soda until its weight had been increased in a dry state to a certain extent, and then, when it was nitrated, new nitric acid was born, as the other nitric acid penetrated the mass, and the whole lot thus became true gun-cotton, quite insoluble in alcohol and ether. In this manner the smoke nuisance was completely done away with, and these gun-cotton primers have since then been manufactured by us in large quantities, and are still being manufactured at the present time.

"Some years ago, I received a large number of cartridges from the States, and also some gun barrels made by Messrs Pratt & Whitney, which were said to be identical with those they had made for the American Government. The projectiles were extremely small in diameter, with a length of about five calibres. Upon trying these cartridges, I found that not more than 2 per cent. of them would hit a target 4 feet square at a distance of 100 yards, and this, when the barrel was firmly locked in position and separate shots fired. I made many experiments. In some, the barrel was greased, and the grease wiped away; in others, a little grease was left in, and, in some, the barrel was quite clean, but in all cases the projectiles failed to hit the target properly. Upon firing at very short range into wet sawdust, I found that all the projectiles had taken the rifling imperfectly. It was then quite evident that the projectiles were too long, and that they turned over on their minor axis as soon as they found themselves free in the air. I arranged ten thin paper screens in a 100 yards, and by firing, I was able to trace the path of the bullet, and the number of times that it had turned over in its flight. Upon cutting one quarter of an inch off the end of the bullet, and filing it into shape, it made a perfect target, ten rounds going into a hole the size of half-a-crown. A very good target was made when only one-eighth of an inch was cut away. By removing only a millimetre, a few hits were made, while with two millimetres nearly all the projectiles struck the target. It will therefore be seen from these experiments that the critical point at which the projectile will rotate on its minor instead of on its major axis is very clearly defined, and may be considered to be five calibres with one turn in thirty calibres.

" Some years ago Sir Andrew Noble lectured before the Royal Institution on the action of explosives in large guns. Among other things he showed some picric acid, with which he made very interesting experiments. He melted picric acid in a saucepan over a Bunsen burner, and cast it into shells. He evaporated it away without setting it on fire. He piled it up and set it on fire, when it burnt away with a smoky flame. He stirred it up with a white hot iron, and did many other things with it which greatly interested his audience. He then said : 'From these experiments one might be led to believe that picric acid is not an explosive at all,' but in order to disabuse their minds of this idea, he showed them a pile of what appeared to be lampblack. He said that he had placed a cast-iron shell, charged with picric acid, in a strong steel receptacle, and had set it off by electricity. Upon opening his steel receptacle, he had found a mass of perfectly jet black dust which he took to be unconsumed carbon. Upon approaching it with a magnet, however, it was shown to be metallic iron in a very high state of division. Nothing could have been shown which would have demonstrated in so clear a manner the terrific violence with which picric acid detonates than these experiments of Sir Andrew Noble. The experiments have been repeated in the States, though with the picric acid under another name."

Much additional information on the above-named subject may be had by reference to the following publications :

Engineering, March 6th, 1896, p. 309. Review of the first volume of S. J. Van Romocki's "History of Explosives," which was followed by two other larger octavo volumes on modern guns, explosive agents, etc.

Engineering, August 2nd, 1901, pp. 156, 157. Reviews the experiments of Sir Hiram Maxim, and treats especially of his 1885 patents. Sir Hiram supplements this in *Engineering* of August 9th, 1901, p. 195.

Engineering, June 4th, 1909, p. 751. Address delivered by Sir Andrew Noble on "The History of Propellants."

Engineering, May 20th, 1910, p. 649. Editorial on "the stability of propellant powders, more especially as regards nitro-cellulose powder, the French explosive compound."

Engineer, March 23rd, 1883, p. 225. Paper read by Prof. Abel, before the United Service Institution, on the new explosive invented by Mr Nobel.

Engineer, November 8th, 1889, p. 560. Historical notes, on explosives and blasting, by Oscar Guttman. His work on the "Manufacture of Explosives" was reviewed in *Engineering* of March 26th, 1897, pp. 394, 395, and the Bibliography of Explosives appears at pp. 410–427 of the second volume.

Engineer, February 3rd, 1893, p. 108. Letter of A. Noble, F.R.S., C.B., on "Velocities with Modern Guns and Explosives," taking as types both ballistite, due to Alfred Nobel, and cordite, due to Sir F. Abel and Professor Dewar. See also *Engineer* of February 17th, 1893.

Engineer, April 11th, 1890, p. 303. Paper on explosives, read by Ernest Spon before the Civil and Mechanical Engineers.

North American Review for February 1899, p. 142. Letter on "Experiments with High Explosives in Large Guns," by Hiram S. Maxim.

Consult also :—*Eclectic Engineering Magazine*, vol. xxxi., p. 10 ; *Nature*, vol. ii., p. 326, and vol. xli., pp. 328, 352 ; *Forum*, vol. ix., p. 579 ; *Science*, vol. xvi., p. 157 ; *Scribner's*

Magazine, vol. iii., p. 563 ; *Independent*, vol. 52., p. 2424 ; *Journal of the Franklin Institute*, vol. cxlvi., pp. 375, 457 ; *Journal of the Society of Arts*, vol. xliv., p. 555 ; *Historic Papers on Modern Explosives*, by G. W. M'Donald, 1912 ; *Notes on Military Explosives*, by Erasmus M. Weaver, New York, 1917, chap. iv., pp. 98–134.

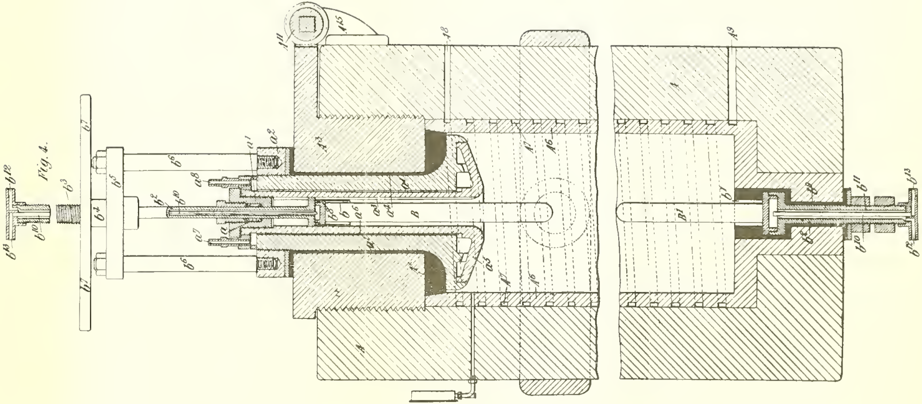
EROSION OF GUNS

THIS was a subject that continually engaged the attention of Sir Hiram Maxim, and, as his several dictations show, he suggested many remedies for the evil that had likewise all along been studied in its many phases by numerous scientists, whose names are given below.

Sir Hiram's latest review of the subject was made, October 9th, 1916, as follows:

" The introduction of smokeless powder and the demand for enormously high pressures and velocities has greatly increased the erosion in large guns. Many of the largest and the most powerful guns to be found in Europe to-day can only be fired a comparatively few rounds before they become so badly eroded as to be practically useless.

" I am aware of the fact that there are several theories in regard to the question of erosion. I think, however, if anyone will give the matter sufficient thought, they cannot fail to be convinced that erosion is caused by



PATENT No. 20343. NOVEMBER 11, 1897
MAXIM'S METHOD OF MANUFACTURING ELECTRIC LAMP FILAMENTS

the very rapid passage of incandescent gases past the driving ring of the projectile. If we examine the chamber of a large gun which has been fired, say, fifty rounds, we shall find that the mushroom head of the De Bange obturator is not scored in the least. We should also find that the rear part of the chamber is quite smooth. There will, however, be found a few hair lines in the neck of the bore, and it would therefore appear that the white-hot gases do not chemically affect the steel to any considerable extent.

"When white-hot powder gas is brought into direct contact with steel, that part which touches the steel is very quickly deprived of its heat, because the specific heat of steel is vastly greater, volume for volume, than the specific heat of powder gases.

"Suppose now that we examine that part of the rifling of the gun where the pressure is greatest and where the greatest amount of gas escapes past the driving ring of the projectile, we shall find the surface deeply scored and pitted, and we shall find that the erosion is greatest on that side of the rifling which does no work in rotating the projectile. The gas may cut away the back side of the rifling, while the working edge of the rifling may remain quite perfect and smooth. This is brought about on account of a slight crack being open between the copper and the steel. If we took into consideration the actual length of time required for cutting away the steel, we should find that the powder gases have dissolved the steel as fast as a stream of hot water would cut away a piece of ice. It has been observed that, at the breech block end of the chamber, no cutting away took place when there was little movement of gas and when very few volumes of gas had come into contact with one volume of steel, but if in the rifling —where an opening presents itself between the driving band and the rifling—many volumes of the gas, moving at a terrific velocity, came into contact with one volume of steel the steel would be heated and blown away with great rapidity.

"There is no question at all but that erosion in large guns is caused by incandescent gases passing the driving band of the projectile.

"In England, where heavy proof charges are fired, some large guns are very seriously damaged by erosion before a single service charge has been fired, and only a few service charges can be fired at all before the rifling is so badly cut away as to greatly interfere with the accuracy of the arm.

"Suppose now that, instead of depending altogether upon the copper gas check for preventing the gases passing the projectile, we should employ some means which would make an absolutely gas-tight joint between the projectile and the bore of the gun. Suppose that our projectile were provided with a semi-plastic asbestos ring arranged in such manner that when the gun was fired the semi-plastic asbestos ring would be subjected to a pressure, say, twenty per cent. greater than the pressure in the chamber itself. On firing, this plastic ring would be pressed outward with great force, and it is obvious that it would be quite impossible for the gases to pass through a plastic mass which was already under a pressure considerably greater than the pressure of the gas itself.

"I have taken out several patents in my own name, and several in conjunction with Lieutenant A. Trevor Dawson, for devices for completely preventing erosion in large guns. It may be said that these obturating gas checks, which may be applied to any form of projectile, add something to the cost, but the cost is as nothing compared with the damage done to the arm.

"I hope I may be permitted to make here a record of the fact that I was the first to patent an obturating gas check, likewise the first to oppose the passages of gases alongside the projectile, by employing a semi-plastic material subjected to a pressure greater than the pressure in the chamber of the gun, and that I was also the first to patent a device which would create this pressure by arranging parts in such manner that the gas pressure operated on a surface considerably larger than the surface of the plastic ring to be compressed."

On the 30th of November 1901, Sir Hiram had previously written the following:

"When I first commenced making automatic guns in London, a great number of engineers, and of military and naval men, visited my little workshop. I remember very distinctly that when Vavasseur, the inventor of the Vavasseur carriage, called on me, he said: 'The gun is certainly very ingenious. It undoubtedly fires with very great rapidity, but I am very much inclined to think that the guns which we already have fire quite rapidly enough. If you could discover some means of preventing erosion in our large guns, it would be much more useful to us than anything which you could possibly do with a view of increasing the rapidity of fire. Erosion is the great difficulty that we have to contend with.'

"This set me thinking on the question of erosion, and some years later I devised a plan of preventing erosion in large guns, and wrote a little pamphlet on the subject. Upon taking my plan and my pamphlet to Canet, in Paris, he said: 'Yes, erosion certainly destroys our guns very quickly, and there have been a great number of plans formulated for preventing it, generally by people who know nothing of the subject. However, it would appear to me that you are quite right in your argument that the greater part of the erosion is due to the gas passing the driving band at the instant of firing. It is the only hypothesis which is supported by reason or logic, and it would seem that there is but one way to prevent this, which is to oppose the passage of the gas by the use of a semi-plastic substance, which is momentarily put under a pressure considerably higher than the pressure of the powder gases in the gun, according to the system shown in your patent. I have no doubt that your system would prolong the life of a gun tenfold. But,' he continued, 'you never will get it into use. Nobody will have it,' I asked, 'Why?' 'Because,' said he, 'no one wishes to make guns last longer than they do at the present time. There is no country where those who have any say in the matter are not interested either directly or indirectly in the production of guns, or of steel for making guns. Suppose now that you increase the lifetime of a gun tenfold. It means a falling off in the money spent on guns to just that extent that you prolong the life of the gun, or a drop of 10 to 1. I am dead against you myself. I certainly do not wish to see your invention succeed.'

"He then went on to say: 'At the present time we are making some very high-power guns. Suppose, when these guns are finished, that they fire four proof charges. Then the gun is mounted on its carriage, a few rounds are fired to prove the carriage and the hydraulic buffers. Next the gun is mounted on the ship, and fires several rounds to test everything relating to the gun, the carriage, and the ship. Then perhaps a new fuze, or a new shell, or a new powder presents itself, which has to be experimented with, and the gun is again fired a few times. Then a few rounds have to be fired to teach the men how to work the gun, and to keep them in practice. Shots have occasionally to be fired in target practice, and by the time all this has taken place perhaps thirty rounds have been fired—not a very large number—and the gun has a lifetime of firing thirty rounds more. Suppose that only a few rounds are fired each year, in a comparatively short time the gun is finished, and a new one has to be purchased. The finest guns that we are making at the present time can only be fired sixty rounds, when the rifling becomes so badly worn that the projectile is not rotated, and consequently will not hit the target.'

"This was certainly very discouraging. On my return to England, I made several attempts to have my system submitted, but found it quite impossible to have it tried in accordance with the patent. It is true that several trials took place with a modified form which some artillerists believed might work, but it lacked the one essential feature—that is, the semi-plastic material under a pressure greater than the pressure of the gas itself—and up to this day I never have been able to have a single shot fired with an obturating gas check in accordance with my original patent, although I made ten large projectiles for the British Government provided with this gas check many years ago. So I think it will be seen that Canet was about right.

"Suppose now that large guns were in the hands of civilians, that they were used for some commercial purpose, and that the users of these guns had to purchase new guns constantly. When the inventor came out with something that would increase the lifetime of the gun tenfold, every purchaser of big guns would be delighted. All of them would be forced to use it, and the thing would be a success at once. 'The proof of the pudding would be in the eating.' Whenever the system is presented to a Government, of course some excuse has to be offered why it should not be tried, and the various kinds of excuses are extremely interesting. One official in a high position, who was satisfied with the existing state of affairs, assured me that on account of the very superior quality of steel used by his Government there was no erosion in their large guns, and that they would last *ad infinitum*. I told him that experiments had been made in England with every possible variety of steel, and that the erosion in all grades was almost exactly the same. His answer was that all English steel was very much inferior to what they were using themselves, and consequently there was no use in combating a trouble which had no existence.

" The usual excuse for not using the system, however, is to admit that there is erosion, and that it is very objectionable, but that it is not caused by the passage of the gas between the projectile and the bore of the gun, as claimed by me, but that it is due altogether to chemical action. When you ask people with these views how it happens then that the breech-block is not eaten away by the chemical action quite as much as the bore, they are a little upset, but generally manage somehow or other to wriggle out of it to their own satisfaction.

" I think, however, there can be no question that 95 per cent. of the erosion in large guns is caused by the gases passing the projectile at the instant of firing. Everything points in this direction, anyway, and nothing points in the direction of chemical action.

" Suppose now that all our projectiles should be provided with an obturating gas check which would effectually prevent the gases from passing between the projectile and the bore of the gun. The lifetime of the gun would be increased more than tenfold ; indeed, I think fully twenty-fold. The cutting away of the bore would take place in a regular manner ; no deep pits or holes would be scooped out ; and as the shoulder at the beginning of the rifling wore away, the gas check could be set out so as to have a greater diameter. It would prevent the shot from being over-rammed, and would keep the volume of the gas chamber of the gun constant. This would be an advantage.

"Then again, proof charges have to be fired, and on account of the pressure being very high, the erosion becomes severe. I have known a gun made by Armstrong to be completely worn out by firing four proof charges and two service charges. The gun, however, was not designed by Armstrong, but by the official of a foreign Government, who aimed at getting extremely high velocities. One is never in a hurry when firing proof charges. Suppose now that each shot to be used in proving a gun should be provided with a very thick obturating gas check, and that when the shot had been firmly rammed home into position, the screws should be tightened up so as to press this gas check outward, making an absolutely air-tight joint. When the gun was fired, no gases could escape, and practically no erosion would take place. The additional cost of making such projectiles would be infinitesimal as compared with the wear and tear of the arm. But, unfortunately, it requires a little different shape to the chamber, to use this gas check, than with the ordinary copper-driving band alone. It is necessary that the chamber should be of such a shape as to have a straight cylindrical part just at the back of the rifling for the gas check to be set out against, instead of having the enlargement commence at the beginning of the rifling as in the ordinary arm. However, our own experiments have shown that nearly all Service guns can be greatly improved by increasing the volume of the powder chamber. If four inches should be removed from the muzzle of our high-power guns, the velocity would only be very slightly reduced. If we press the projectile four inches further forward, thus reducing the length of the rifling to the same extent, and using exactly the same pressures, of course the reduction in velocity would be the same. But whenever we move the projectile forward, we increase the volume of the chamber, which enables us not only to use a larger powder charge, but also increases the relation between the volume of the powder charge and the volume of the bore, which gives a considerably higher final pressure in the gun—that is, it makes a fuller diagram—so that in most cases the movement of the projectile forward in the arm increases instead of diminishes the velocity of the projectile.

"When once we have projectiles which will not wear out the arm, it will be possible to do a great deal of target practice, and to drill the man in a much more thorough manner than is possible at the present moment. Then, again, black powder for a bursting charge, which is really the best for target practice on account of the great volume of smoke, can be rendered perfectly safe against going off by the concussion of discharge by mixing with it a small percentage of the compound which I have already described. If high explosives are required, picric acid is a long way ahead of everything else, and, as has already been demonstrated by Turpin, as well as by the British Explosives Committee, and by myself, picric acid may have any degree of insensitiveness imparted to it by combining it with only a small percentage of di-nitro-benzol and vaseline. I think I have already proved that a fuze can be made which is perfectly safe under all conditions, and that it is quite possible to use large charges of fulminate of mercury if desired, without the least danger of premature explosions. However, I have also shown that a perfectly reliable and effective fuze may be made in which no sensitive, dangerous, or unstable explosive is employed at all. With all these, it would be possible to have our large guns and ammunition in such a condition that any amount of practice and target firing could take place without the bugbear of wearing out the rifling, or the danger which, up to this time, has always been too apparent when large and heavy guns are discharged.

"I am aware of the fact that the pure tri-nitro-cellulose powder employed in the United States of America is not so destructive to the bore of the gun as the English cordite, or the continental ballistite. In connection with this, it may be interesting to recall the fact that I made a very good apparatus some years ago for ascertaining the relative amount of erosion that took place with various kinds of powder. As has been said on page 48, the experiments were put in the hands of Professor Vernon Boys, one of the cleverest scientific men in England to-day. Professor Boys found that the erosion with smokeless powders which were in use at that time was just about in proportion to the amount of nitro-glycerine employed, and that the British cordite, containing 58 per cent. of nitro-glycerine, produced four times as much erosion as my own smokeless powder, which was officially known as Maximite (and, by the way, "Maximite" is a trademark belonging to our Company), containing about 13 per cent. of nitro-glycerine. It was also found that the amount of erosion would have been very much greater in the British cordite than it is at the present moment if they had not employed vaseline. Powders with only 40 per cent. of nitro-glycerine without vaseline were quite as destructive to the rifling as 58 per cent. of nitro-glycerine, with vaseline, and this is accounted for by the fact that with vaseline the quantity of carbon di-oxide was diminished, and the quantity of carbon mon-oxide increased. Carbon di-oxide, on account of its extremely high temperature, is much more destructive to rifling than carbon mon-oxide, which has approximately twice the volume for the same weight and temperature, or the same volume at half the temperature."

The following are the extracts which, upon another occasion, Sir Hiram made from his Address before the British Explosives Committee:

"With regard to the prevention of erosion, at the present moment it is well known to all artillerists that the new nitro-cellulose powders do not erode a gun as rapidly as nitro-glycerine powders, but I feel convinced that there will be a tendency to increase the range of guns by increasing the initial pressure, and this again will bring back a higher pressure and the temperature which is so destructive to our large guns. I think, therefore, that we ought to provide against erosion not only by changing the chemical constituents of the powder, but, at the same time, we should strike at the very root of the evil and eliminate it altogether, at least 95 per cent. of it. I know that there is some conflict of opinion regarding the question as to what produces erosion. I think, however, if we give the subject sufficient thought, we shall all agree that erosion is caused by the hot gases passing the projectile. If this were not the case, as has already been remarked, the breech-block and the rear end of the chamber of the gun would be eaten away quite as much as the bore, but these are not injured in the least. When one volume of gas comes into contact with one volume of steel, the gas that comes in immediate contact with the steel is chilled, but when a hundred volumes of hot gases are brought into violent contact with one volume of steel, such as is the case when these gases pass the projectile, the steel is then not only highly heated and softened, but it is at the same time washed away quite as rapidly as ice is washed away with hot water. There is not the least question but what nineteen-twentieths of this erosion would be prevented if no gas passed at all. There is only one way to prevent these gases from passing, and that is, as before stated, to oppose them by some substance of a semi-plastic nature which, at the instant of firing, is subjected to a pressure greater than the gas pressure itself. This is very easily accomplished if we attach a species of junk ring to the base of our projectile, and place between it and the projectile a ring of some semi-plastic substance like the ordinary vulcanized fibre or woodite. If we make the junk ring of such a form that this semi-plastic ring is subjected at the instant of firing to a pressure 20 per cent. greater than the gas pressure in the chamber, it will be set out into the rifling with great force, so that instead of the gases passing this ring, its substance will have a tendency to be pressed back into the chamber against the pressure of the gases. This is the only way that this evil can be corrected. It has been completely worked out by me in a simple and effectual manner, and, moreover, this junk ring makes an excellent protection to a new system of fuzes which I have recently designed."

The references above alluded to are as follows:

Van Nostrand's Engineering Magazine, vol. xii., pp. 375, 376, and vol. xxxiv., pp. 279, 280, for Capt. A. Laufroy's "Cause of Erosion in the Bore of Guns."

Revue Technique, for April 10th, 1889.

Eclectic Engineering Magazine, vol. xii., p. 375, and vol. xxxiv., p. 279.

Engineer, February 26th, 1875, p. 149, on "The Erosion of Rifled Guns," a paper read by Mr Charles Lancaster before the Institution of Civil Engineers.

Engineer, September 11th, 1891, pp. 207, 208, on "Erosion in Large Guns."

Engineer, July 15th, 1910, p. 68, on the "Erosion of Guns," referring to an admirable essay on erosion by Lieut.-Com. H. E. Yarnell, U.S.N.

Engineer, October 14th, 1910, p. 415, and also pp. 421, 422. The latter is an exhaustive article on erosion, by Prof. P. R. Alger, U.S.N.

Engineering, June 4th, 1909, p. 751; July 21st, 1911, p. 95.

Scientific American, November 5th, 1898; October 15th, 1910; January 12th, 1916; August 5th, 1916; November 18th, 1916; Volumes xcii., p. 4; xciii., p. 394; xcv., pp. 186, 226, 231, 426; xcvi., pp. 66, 70, 131, 306, 307; xcvii., pp. 162, 163; ciii., pp. 194, 290.

American Inst. Mining Engineers Bulletin, by H. M. Howe, February 1918, No. 134, p. 335.

Consult also British Patents: 1898, No. 26263; 1903, No. 18514; 1908, Nos. 12843 and 23840.

FUZES

THE several British Patents obtained by Sir Hiram Maxim, which properly come under this head, are :

No. 6591, May 30th, 1885 ; and No. 2090, February 14th, 1885.

No. 13534, October 22nd, 1886, " . . . improvements in time fuzes and in percussion fuzes . . . adjusted to regulate the time during which the fuze mixture will burn before it ignites the bursting-charge." Claims 10 to 16 all relate to the employment of a time-fuze.

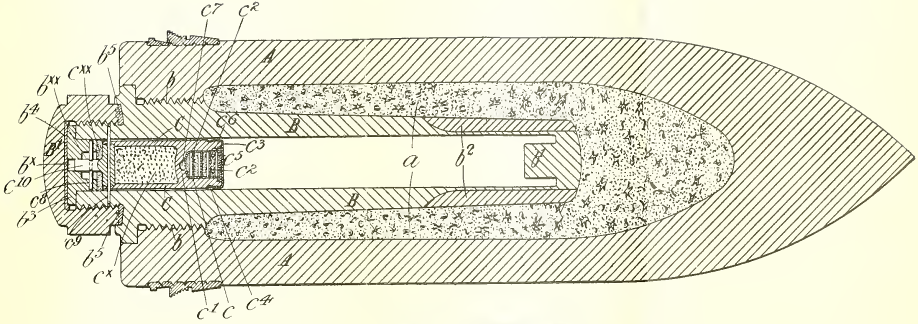
No. 16672, December 18th, 1886.

No. 17252, December 15th, 1887. Treats of delayed action fuze, and the principle on which it works is referred to below.

No. 16694, August 20th, 1901. The completed patent bears date May 20th, 1902. It has eight claims, all relating to a delayed action fuze, and is entitled " Improvements relating to fuzes for armour-piercing projectiles."

No. 19017, August 29th, 1902. The completed patent is dated May 11th, 1903. It has six claims, all relating to a delayed action fuze, and is entitled " Improvements in fuzes for explosive projectiles."

Sir Hiram Maxim's private communications on the subject of fuzes are as follows :



PATENT NO. 19017. AUGUST [illegible], 1902
MAXIM'S IMPROVED FUZES FOR EXPLOSIVE PROJECTILES

" In 1885, when my large gun for throwing aerial torpedoes was being discussed, I was often asked what sort of a fuze I intended to employ. If my projectiles went off by impact, why would they not go off at once on touching the water ? How did I get the delayed action which enabled them to plunge some distance into the water before the explosion actually took place ? Then again the question came up : Suppose the fuze went off in the gun—what then ? Would not torpedoes ready fuzed for use be extremely dangerous customers to have on board a battleship or cruiser ?

" It appeared at the time that there was only one way in which this difficulty could be met and successfully combated, and that was to place the fulminating and the secondary charges at a considerable distance from the main charge, and in such a position that if they went off accidentally or prematurely, they would not ignite the main charge. In order to accomplish this I placed the fuze in a tube at a considerable distance to the rearward of the projectile. When the gun was fired, the inertia of the fuze, which was a large one, sheared off a pin. Then when the projectile met with any considerable degree of resistance, the fuze moved forward and entered the base of the projectile where the primer was brought in contact with a firing pin, and the secondary charge, which was strong enough to rupture the shell and communicate the fire to the main bursting-charge, detonated. By this arrangement I was not only able to place the fuze in a perfectly safe condition so as to obviate all danger from prematures, but at the same time it gave the necessary delayed action, which is always required with shells of this kind. The principle on which this delayed action fuze works will be found described in my patents, No. 6591 of May 30th, 1885, and No. 17252, December 15th, 1887, the drawings of which show the detonating charge at a considerable distance from the main charge. It would appear to me that all successful fuzes to be used in aerial torpedoes or for armour-piercing projectiles must of necessity be made on the plan foreshadowed in this patent.

"In 1888 I fitted up a large workshop with American tools for the manufacture of fuzes on an extensive scale, and since that time we have manufactured an immense number of various kinds of fuzes, including a considerable number of very elaborate experimental fuzes for the Government. At the present time we are turning out several thousand fuzes of various kinds every day.

" When ordinary black powder, which is easily ignited, is fired from a low-pressure gun, there is very little danger of prematures. When, however, the pressure and velocity are increased, we find that the danger is also increased. With high-power modern guns, it is safe to say that every part of the projectile sets back as relates to the base which receives the pressure ten thousand times its own weight. In the case of black powder, the set-back is sufficient in all cases to cake the charge, and, in many cases, to set it on fire. However, a premature with black powder is not a very serious affair. It may injure the rifling, or increase the recoil sufficiently to break the mountings, but it seldom destroys the arm. When, however, very high explosives, such, for example, as picric acid, are employed, a premature not only means the destruction of the gun, but in many cases the death of the detachment as well.

" It is quite safe to fire pure picric acid from a high-power gun, and it has often been suggested that if this high explosive can be fired from a large gun without going off by the shock of discharge, certainly it must be very difficult to set it off after it has been shot from a gun. One would have to employ a very large and powerful fuze, and a fuze must of necessity have something in it that will go off. How, then, is it possible to arrange the fuze and the charge in such a manner that the premature detonation of the fuze will not set off the main charge? My answer to this has always been: Place the fuze which carries the primer and the secondary charge in such position that a premature explosion will not set off the main charge. There are many ways of accomplishing this. In several fuzes which I have designed, the detonating charge is placed in the rear end of the projectile, and strong steel shutters are interposed between this charge and the main charge, the shutters being arranged in such a way that they are securely locked together in the shell, but upon firing, the set-back unlocks them from each other, and the centrifugal action throws them outward, when they again become locked in their outward position, thus leaving a free communication to the inside of the projectile. By this arrangement it is quite impossible to open the communication into the shell except by the enormous pressure set up by the powder gases followed by very strong centrifugal action. When the projectile strikes the target, such, for example, as an armour plate, it may lose, say, three-quarters of its energy and half its velocity. Suppose its striking velocity should be 2000 feet per second, and that this velocity should be reduced, in passing through the armour plate, to 1000 feet per second, the detonating charge would still practically have its original velocity of 2000 feet per second, which would cause it to travel forward as relates to the projectile, and whenever it came to the end of the tube in which it moves, it would be detonated, and so detonate the main or bursting charge. It will therefore be seen that such a fuze is not only safe, but gives the necessary delayed action, which is so important in all armour-piercing projectiles.

"I have designed fuzes in which various kinds of fuze mixtures are employed. I have designed several in which large charges of fulminate of mercury may be safely used, but in England the regulations do not allow fulminate of mercury to be employed in large shells on board ship, and never under any conditions where high explosives, like lyddite and picric acid, are used as bursting-charges. In order to meet these regulations I have designed a fuze in which the shutters are dispensed with. The fuze is made perfectly safe, however, because there is nothing in it which can be considered at all dangerous. When, however, the projectile strikes, the fuze moves forward into the body of the projectile, and is detonated by impact, the detonating charge being nothing more nor less than common smokeless powder of the ballistite type, while the intermediate charge which communicates the explosion to the modified picric acid may be either a mixture of picrate of ammonia and nitre, pure picric acid, or both; or smokeless powder may be advantageously employed. In all cases, the secondary charge is large and powerful. It is believed that this last-named fuze meets all the requirements of the British Government, and it is believed by us to be the first fuze in which all the Government conditions are fulfilled. It has few parts, is of great simplicity, and, as there is nothing about it that can be considered dangerous in the least, it is proposed to fuze the shells where and when they are loaded, and to keep them in a fuzed condition ready for instant use."

The later forms of fuzes designed by Sir Hiram were worked on the same principle as were the fuzes shown in his early patents. From his several descriptions the following extracts have been made. One form is "a fuze in which the fulminating charge is shut off from the main charge by means of a single shutter. In a fuze of this kind, any sort of a compound may be used because a premature explosion will only result in the blowing off of the base cap of a projectile." With this he introduced "an obturating gas check made of soft vulcanized fibre, and having cavities or annular spaces which are filled with wax. This obturating band is sufficiently soft to be set out by the screws that hold the base plate in position so as to enable the plastic material to be set out as the chamber wears away, thus preventing over-ramming. This is for the ordinary Service chamber. When, however, a gun is made expressly for using an obturating gas check, the chamber should be so constructed that when the gun is fired the unbalanced pressure subjects the ring to a pressure of about two tons to the square inch greater than the gas pressure in the gun. This sets the plastic material outward, prevents the escape of gas past the projectile, and, as the projectile advances into the rifling, the brass plate between the obturating band and the base plate is bent back, covers the corner of the base plate, and so prevents injury to the rifling. The brass plate should never be made large enough to extend to the rearward of the base plate, otherwise the high pressure of gas as the projectile escapes from the muzzle of the gun will turn it outward, where it will catch the wind and feather the projectile."

The drawing of another form described "a 9-inch shell in which two steel shutters are employed, showing that when the shutters are in the closed position they are held fast by two small steel bolts. When, however, the gun is fired, the set-back of these bolts liberates the shutters, which are thrown out by centrifugal action, and then, as soon as the acceleration due to the gas pressure ceases, the steel bolts are thrust forward by spiral springs and lock the two steel shutters outward, leaving a completely free path into the interior of the projectile. The set-back of the bolts also deforms the two copper pins. It will be seen that with a fuze of this kind it is quite impossible for a premature explosion of the fuze to have any effect at all upon the main charge."

Other drawings showed "a 6-inch armour-piercing projectile with a modified black powder charge. The fuze is small in size and is provided with an ordinary cap, the same as that employed for small fuzes in small projectiles. This shell is provided with two shutters, which operate in the manner already described. The inner tube which gives the delayed action is, I think, a little too light for the purpose as the set-back of the powder charge might compress it. The obturating gas check is of two kinds of material, the forward one being of soft woodite, and the rearward one of vulcanized fibre." There was also shown "a 6-inch armour-piercing projectile with a delayed action fuze and two shutters, but the shutters operate in a totally different manner from those heretofore shown. They are placed loosely in a circular chamber, and are held together by two steel pins and a copper strip. When the gun is fired, the centrifugal action straightens out the copper, and the pins act as guides for keeping the shutters in position.

"All the above-named systems employ fuzes in which the chamber holding the fuze is completely shut off from the interior of the projectile, the fuze in all cases being placed in such a position that a premature blows off the base plate or bursts the tube at the rear instead of igniting the main charge, and all of these systems permit of the use of any sort or kind of fulminating charge that one may wish to employ. But as fulminate of mercury, and everything of a similar nature, is objected to by military and naval authorities, I have designed yet another system which is quite different from all the foregoing.

"If a fuze is to contain nothing of a dangerous nature—nothing that will deteriorate with age, and nothing that will go off by any impact or shock that a projectile can receive, except striking an armour plate—it does not become necessary to provide any shutters or other device between the fuze and the main charge." In this system Sir Hiram observes "the fuze is large in size, and is placed in a long tube inside a projectile. The fuze really carries three charges, which we might call A, B, and C. The fuze is held back in the shell by two strong copper pins, and the movable part of the fuze is secured to the fuze itself by a much stronger pin. . . . When the gun is fired, the powder gases deform the base cap . . . and, at the same time, subject the washer of woodite to a pressure considerably higher than the gas pressure in the gun. This effectually prevents the entrance of gas into the projectile. At the same time, the set back of the fuze as relates to the projectile shears off one of the copper pins, and bends the other one backwards in the form of a crank. . . . The bent copper pin prevents the fuze from moving forward into the projectile during flight. When, however, the projectile meets with any considerable degree of resistance, the fuze moves forward bodily, as relates to the projectile, and shears off this bent copper pin. The fuze then is quite free to move forward in the tube, and continues to do so until it comes in contact with the end of the tube which limits its travel, and as it is suddenly checked in its rapid course, the forward end comes in very violent contact with the end of the tube, and at the same time the momentum of the movable inside part shears off the third and strongest copper pin, and allows the whole inside to move forward as relates to the body of the fuze. This violently compresses the smokeless powder or other material contained in the forward end of the fuze, which we may call the 'A' charge, and produces an explosion which is communicated to the 'B' charge, and the 'B' charge in its turn explodes with great violence, setting off 'C' charge and bursting the tube. . . .

"Smokeless powder of the ballistite type is quite safe to use in small projectiles, and it will be observed that the quantity used, as the 'A' charge in the fuze, is not great enough to be set off by the shock of discharge. Moreover, smokeless powder is a well-known compound, in which everyone has confidence and which does not deteriorate in the least by keeping. The 'B' charge which is loaded into the inside movable tube of the fuze may be of any suitable safe fuze compound, such, for example, as picrate of ammonia and nitre; while the 'C' charge, the last in the fuze to go off, may be either pure picric acid, or picric acid combined with other materials; or the whole may be some modified form of safe smokeless powder.

"Of course, I do not confine myself to any particular kind of fuze mixture as there is some dispute as to which is the best material for setting off picric acid. Experiments, however, have shown that primers of compressed gun-cotton work very well, and the difference between the explosion set up by a gun-cotton primer and smokeless powder, which is largely gun-cotton, is not very great.

"The English experimental officers have found that picrate of ammonia and nitre make a very good intermediate charge to place between the first detonating charge and the picric acid to be set off. The formula is: Fifty-six parts of picrate of ammonia, and forty-four parts of nitrate of potash, the whole being very finely ground, and intimately mixed. It is claimed that such a compound cannot be set off by impact, or by a blow, but that it may readily be set off by the explosion of other chemicals, such, for example, as gun-cotton, or smokeless powder."

Additional particulars of interest will be found more particularly in *Scientific American*, vol. 104, p. 411, and in the illustrated article, "Fuzes for Field Gun Ammunition," which appeared at pages 486, 487 of *Engineering* for April 22nd, 1892.

GUN FOR ATTACKING ZEPPELINS

WHEN Sir Hiram Maxim was informed that some model guns of about an inch bore, which he had made for effecting the destruction of Zeppelins by aeroplanes, were considered too small for the purpose by the Government officials, he designed a much larger gun that would fire an incendiary shell which, he thought, could not fail to set the Zeppelin on fire. In making his original apparatus he had not contemplated reloading while in the air, but a leading member of one of the Government Committees insisted that the proposed gun should be one which could be loaded at the breech while the aeroplane was in flight. Sir Hiram very reluctantly consented to the change, and designed a cartridge which gave a constant stream of fire from the time it left the gun until it had travelled at least a thousand yards. But he showed a marked preference for a muzzle-loader, in accordance with his original plan, and it so happened that the desired trials

Fig. 1.

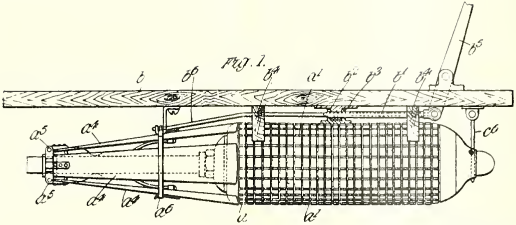


Fig. 4.

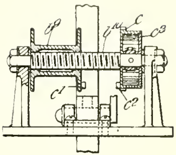


Fig. 3.

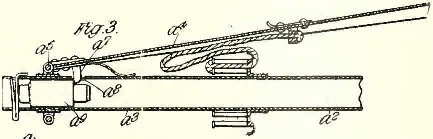


Fig. 5.

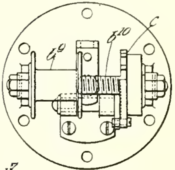
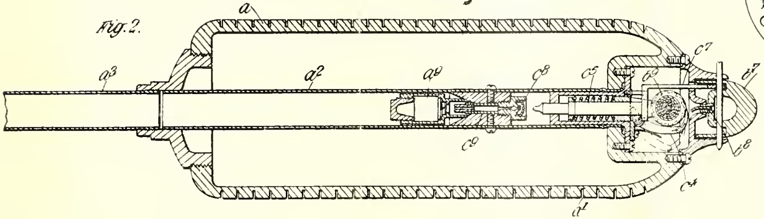


Fig. 2.



PATENT No. 8220. APRIL 1, 1911
MAXIM'S IMPROVEMENTS IN BOMBS FOR USE WITH FLYING MACHINES

were not made. Later on, October 30th, 1916, he dictated his views as follows :

" I am ready to provide a gun having a bore of about one and a half inches. There is no difficulty about it at all—simply a strong steel tube loaded from the muzzle. When a flying machine, armed with this weapon is in range of a Zeppelin, it will be only necessary to pull the trigger ; then a dozen or more shots will discharge themselves at intervals of from two to twenty seconds, as may be desired. I would recommend that this simple, cheap and effective arm should be secured solidly to the flying machine. As a whole, I think it would be best to have two discharge tubes or guns instead of one. One could be loaded with about six cartridges that have a relatively long range, and the other with ten short cartridges.

" When the last shot has been fired, the flying machine should adopt another system of attack which I will describe later on. My original apparatus was so extremely simple, cheap and effective that had it been taken up as first exhibited by me, there would be no danger from Zeppelins at the present time, and many lives and a vast amount of property would have been saved. If we have flying machines that can travel faster than a Zeppelin, and if they are armed with one or more of these guns, the Zeppelins will have no show at all.

"In the models submitted which had a bore of one inch, the barrels were made of solid drawn tubes, and they stood the necessary pressure very well. Suppose now that we wanted these guns in large quantities, it is only necessary to obtain a lot of solid drawn steel tubes about 8 feet long, having a bore of $1\frac{1}{2}$ inches and a thickness of about $\frac{3}{16}$ inch. These will stand the necessary pressure, and such guns would be very light, and could be turned out very rapidly at a very low price.

"An aeroplane armed with two of these guns, when it had come within a thousand yards of a Zeppelin, would commence to fire its six long range cartridges at intervals of about twenty seconds, and if these were not effective, the aeroplane would approach still nearer, and would fire the ten shorter cartridges.

"Each cartridge would carry a trail of fire containing pulverized magnesium which would be sure to ignite the hydrogen if a hit were made.

"We should not lose sight of the fact that a Zeppelin presents a mark which would be equal to a target 60 feet high, and 500 feet long. The guns would not be trained at all as relates to the aeroplanes ; it would only be necessary to aim the aeroplane at the Zeppelin in order to hit it. In the event of the aeroplane wishing to attack another Zeppelin after the first one had been destroyed, I should recommend a peculiar means of attack. Assuming that the aeroplane can travel faster than the Zeppelin, it could fly over the Zeppelin and let down a bomb attached to a cord or wire, the bomb being provided with a lot of sharp hooks. In dragging this across the Zeppelin some of the hooks would catch, which would put a strain on the cord, and cause the bomb to explode. This would not only tear a large hole, but at the same time, set the hydrogen on fire.

" As I am dead sure that my system is all that is required to keep the Zeppelins out of the country, I propose to leave no stone unturned in attempting to get it into the service.

" It will certainly be adopted sometime by some nation, and its early history will form a chapter of interesting reading in the military publications of the future."

THE LEWIS GUN

IT has often been said that the two most prominent and efficient machine guns employed in the present world-war, are the Maxim and the Lewis, and it is therefore thought well to give here a few particulars concerning the last-named, more especially as Sir Hiram made mention of it in that part of the dictation on the Maxim Automatic Gun, which appears herein on page 14.

The above-named gun, is the invention of Colonel I. N. Lewis, formerly of the Coast Artillery Corps, U.S.N., and is one of the three machine guns now in use by the United States Army, the other two being the Maxim and the Benet-Mercier, which latter is, like the Lewis, of the gas operated type. The Lewis gun, it has been well said, is as distinct from a machine gun as a revolver is different from a rifle, although both arms fire the same calibre ammunition. Some of the many claims made for the Lewis gun are that its forty-nine parts, (exclusive of the sights) can be assembled or dismounted in thirty seconds with no other tool than the nose or point of an ordinary bullet in a cartridge . . . its normal rate of firing is five hundred rounds per minute . . . it can be fired continuously without overheating, without appreciable recoil, and in any position, whether from a tripod, when resting on a bank, from the shooter's knee, or even from the shoulder. In this gun, the cooling of the barrel is brought about by means of air currents. As each cartridge is fired, there is a fresh passage of air which causes the cooling of the barrel without the use of water or of any mechanism. The several patents covering the mechanism of the gun are the property of the Belgian "Armes automatiques Lewis Company," and the manufacturing rights belong to the "Birmingham Small Arms Company."

The tests to which the Lewis gun was subjected in competition with the Benet-Mercier showed that, after the last-named had fired eight or ten shots during five minutes of fire, and then became jammed, the Lewis gun fired as many as 188 shots in fifty-three seconds, and stood perfectly all the sand and mud tests as well as the tests made with deformed cartridges and battered shells.

In an illustrated article given by the *Engineer* of December 5th, 1913, will be found results of the public demonstration of the Lewis gun made at Bisley, November 27th, 1913, as well as additional particulars regarding the gun itself. While at Bisley, Colonel Lewis remarked that he estimated the accurate life of a barrel in his gun, under service conditions, at 12,000 rounds, using United States ammunition, and at 5000 to 6000 rounds when employing English cordite ammunition.

Amongst the many published accounts of the Lewis gun, can be singled out to advantage those given by *Engineering*, November 8th, 1912; December 5th, 1913; September 25th, 1914; October 16th and 23rd, 1914. Illustrated articles will likewise be found in *Engineer*, November 28th, 1913, and December 5th, 1913, and in the *Scientific American* of August 5th, 1916, November 25th, 1916, and August 25th, 1917.

In this connection, mention should be made of another remarkable machine gun, regarding which much has lately appeared throughout the public prints. Reference is here made to the invention of Major-General Madsen, who some eighteen years ago, was Minister of War in Denmark, and the father of a very prominent scientist managing the Danish Serum Institute.

Through various accounts of correspondents of different technical and other journals, it is learned that, in the Danish army, this Madsen gun is used by the cavalry, four to each squadron, as well as by the coast and fortress artillery. The gun weighs only five pounds more than an ordinary rifle, and, like the Lewis, is easily fired from the shoulder. Madsen magazines, it is said, are so much lighter than those of the Lewis gun that, for every 3600 rounds carried in the magazines, there is a saving of 67 pounds in favour of the Madsen. The gun can be got in and out of action as quickly as an ordinary rifle, on account of its great reduction in weight as compared with that of many other machine guns.

Extracts from the reports of tests made by British army experts, notably during the month of May 1918, prove that the Madsen mechanism is of the simplest kind, for there are no small parts or springs liable to break or difficult to replace, and that, beyond faulty ammunition, the question of stoppages hardly arises. Moreover, the difficulty of a very hot barrel is almost obliterated, as, owing to a new device, the heat does not at all travel through the mechanism of the gun. It is claimed that a change of barrel is only necessary after firing about a thousand rounds, as against five hundred rounds in other guns, whilst one man can easily change the barrel in twelve seconds, against two men in twenty seconds, with the Hotchkiss.

From the press reports of the Government Statement made in the British House of Lords, through Lord Sidney Herbert Elphinstone, and from the discussions that followed, on June 6th, 1918, in answer to a series of questions propounded by Admiral Lord Beresford, it is learned that the present Madsen gun is by many considered " the most wonderful machine of its kind ever invented," and that it is admittedly superior in many respects to either the Lewis or Hotchkiss guns, both for attack and defence. The Marquis of Salisbury remarked that, having inspected the Madsen gun, he was deeply impressed with its simplicity, ingenuity and efficiency, and that he believed it to be " enormously superior to any other gun in existence." In addition, the Earl of Albemarle reported that he had recently witnessed a competition between the Madsen and the Hotchkiss guns mounted on cavalry horses, that "the Madsen was brought into action in fifteen minutes and had discharged something like one hundred rounds by the time the Hotchkiss gun was made ready to fire."

THE FLIGHT OF A PROJECTILE

THE following is a brief explanation of the above which Sir Hiram Maxim dictated in reply to a London journalistic enquiry made June 12th, 1914: "When we fire at long range it is necessary to point the rifle very much above the target that we wish to hit. When the projectile leaves the bore of the gun, it travels coaxial with the barrel only for a short distance, then commences to describe a parabolic curve in the air. The axis of the projectile never corresponds to the curve, it is always approaching but never reaching it. It is the action of the air on the base of the projectile that causes it to assume a position approaching the parabola. If a projectile is over five calibres long, and makes one turn in thirty calibres, it will not travel head on, but will very soon turn over in the air, revolving on its minor instead of its major axis. If the length of the projectile is no greater than five calibres, and it makes one turn in thirty calibres, it will keep head on, or approximately so. When we consider atmospheric resistance alone, fish-shaped would be the very best, but it would be very difficult to make a good target with a fish-shaped projectile. If a gun were fired at a high angle on the moon where there is no atmosphere, it would describe a parabola in falling, but the axis of the projectile would always remain the same, so that at the time of striking the moon's surface, it would not be travelling end on.

"Everything of this kind has already been tried. It is safe to say that when firing at long range one never points the rifle to the target—there is the gyroscopic action and the drift to be considered—but this cannot be described in a few words."

AERIAL NAVIGATION—MECHANICAL FLIGHT

By Sir Hiram Maxim

MANKIND has been seeking some means of navigating the air ever since the days of Icarus and Daedalus. "A goose is able to fly and why should not we fly?" A French mathematician proved that a goose exerted twelve horse-power in flying, while another mathematician who viewed the subject from a different standpoint, wrote an article to prove that a goose only exerted one-twefth part of one horse-power in flying. However, it was only after many years of speculation and experiment that the first machine was made that would lift itself from the earth by dynamic energy. This machine might be compared to an enormously large kite, which, instead of being held up against the wind by a cord, was driven into the air by the action of two large screws and two immensely powerful steam engines, but the steam engine system required altogether too much water. It was not until after the invention and simplification of light petrol motors for use on racing cars that a successful flying machine was made, which like the steam machine was a big kite driven through the air by screw propellers.

I think it will be admitted by all that since the development of a suitable motor, no Science has ever advanced with such rapid strides. This is due to the fact that many of the cleverest scientific men as well as the most skilful mechanicians entered the field, and devoted a great deal of their time to the subject.

S. P. Langley, the astronomer, was certainly a very good mathematician. When, however, I told him how much I had made an aeroplane lift to the square foot he could not believe it. He said it was "too good to be true." My data, however, had not been obtained mathematically, but by actual experiment, and I am now much gratified to learn that the data which I obtained then at so much expense, have been found to be correct in actual practice.

Some recent flying machines have made very remarkable flights covering many hundreds of miles at a very high speed, and the same is true of dirigible balloons, which are now called airships. Nothing, however, has been produced so far to demonstrate that such machines can be used for commercial purposes, that is, for the profitable transportation of passengers and freight. From the very first I have maintained that they can only be employed for sporting and military purposes. When we consider that it would be possible for a continental country with machines no better than those now in use, to drop into London one hundred tons or more of nitro-glycerine in the darkness of one night, or double that amount on a foggy day, I think we must admit that the flying machine is, in reality, a very potent military weapon.

A flying machine is a very light and relatively inexpensive machine, and is capable of flying in almost any kind of weather. It flies at much greater speed, and is much more manageable than an airship, and in case of actual warfare airships would be at the complete mercy of flying machines. Moreover, the airship is so fragile in proportion to its bulk that it is very easily destroyed. When an airship is once out of its shed, a relatively light wind makes it impossible to re-house it. I do not look upon airships as being of any value whatsoever except for spectacular and show purposes.

It will always be much safer to travel by flying machines than by airships, and in warfare the vital spot of a flying machine is extremely small. Hundreds of projectiles may pass through the aeroplane without doing any perceptible harm, but with the airship the whole of its enormous bulk is vital. It is only necessary to ignite the hydrogen in order to bring the whole of the metal work to the ground with a violent crash. Many of the accidents with flying machines of the early type were due to imperfect design and workmanship, and also to engine failure, but these faults are gradually being corrected, and no doubt will soon very nearly disappear; no matter how perfect a flying machine may be, there will always be a considerable degree of danger attending its use. In cloudy and stormy weather there are always very strong eddies in the air, some of these eddies actually rotating, especially in the vicinity of hills, mountains or high buildings. In bright or sunny weather the machine is at any time liable to run into what the aviator calls "a hole in the air," which simply means a zone of small area in which the air is descending at a rapid rate. I know of no better means of studying these "holes in the air" than by observing what takes place in the sun. The body of the sun itself is much hotter, and very much more luminous than the photosphere. The incandescent vapours of the sun are constantly rising up, giving off light and heat, and having their specific gravity increased by being cooled, and as they are heavier than the surrounding vapours they return to the surface of the sun. We are able to study these with the telescope. The so-called sun-spots are nothing more nor less than descending currents of gases which, although very hot, are relatively cold as compared with the surrounding gases, that is, the sun-spots are holes in the photosphere of the sun. The sun, shining on the surface of the earth, heats the air and causes it to rise, and every ton of hot air ascending into the cold regions above, has its place taken by a corresponding weight of relatively cold air. It is a curious fact that whereas the hot air which takes the place of the cold air ascends rather slowly, and over a very large surface, the descending cold air moves with a greater degree of rapidity, and over a much smaller area. This is witnessed by the dreaded mistral that one finds on the shores of the Mediterranean during the winter and early spring. As there is no possible means of showing the locality of these currents they must always remain a source of considerable danger to all kinds of aircraft.

HIRAM S. MAXIM.

AERIAL NAVIGATION—MECHANICAL FLIGHT

Sir Hiram Maxim's different improvements in aeronautical apparatus are embraced in the following British Patents:

No. 16,883, October 25th, 1889. "Improvements in and relating to aeronautic apparatus."

No. 19,228, November 6th, 1891. "Improvements in and relating to aeronautic apparatus."

No. 10,852, June 2nd, 1893. "Improvements in aerial machines.

No. 10,620, April 28th, 1897. "Improvements in aerial or flying machines." This was for an apparatus of the nature of both the aeroplane and helicoptere. The patent has eleven claims and eight pages of illustrations.

No. 20,038, September 23rd, 1908. "Improvements in and relating to flying machines."

No. 7,774, March 28th, 1911. "Improvements in or relating to bombs for use in connection with aeroplanes or flying machines."

No. 8,220, April 1st, 1911. "Improvements in or relating to bombs for use with aeroplanes and other flying machines."

No. 21,722, October 2nd, 1911. "Improvements in or relating to bombs for use with aeroplanes and other flying machines."

It will be seen that the earliest of the above-named patents bears date 1889, but it was not until 1893 that Sir Hiram seriously began his flying experiments upon his forty acres of level ground at Baldwyn's Park in Kent. The progress he made during 1893, and especially during 1894 and 1896, is described fully in the following publications :—

Engineer, London, March 17th, 1893, p. 226. "Mechanical Flight," wherein Sir Hiram details his work after completing the "whirling table" experiments.

Times, London, 1894—August 3rd, p. 3 ; August 7th, p. 5 ; August 10th, p. 2 ; November 1st, p. 5 ; November 5th p. 6.

Times, London, June 16th, 1896, p. 16, for a long communication of Sir Hiram, mainly reviewing the fundamental work of Prof. Langley, who up to the time of his death was Secretary of the Smithsonian Institution of Washington.

One of the papers which Sir Hiram wrote during the last-named year, 1896, contains the following summary :—

"My experiments have certainly demonstrated that a steam engine and boiler may be made which will generate a horse-power for every 6 pounds of weight, and that the whole motor, including the gas generator, the water supply, the condenser and the pumps may all be made to come inside of 11 pounds to the horse-power. They also show that well-made screw propellers working in the air are fairly efficient, and that they obtain a sufficient grip upon the air to drive the machine forward at a high velocity; that very large aeroplanes, if well made and placed at a proper angle, will lift as much as 2½ pounds per square foot at a velocity not greater than forty miles an hour; also that it is possible for a machine to be made so light, and at the same time so powerful, that it will lift not only its own weight but a considerable amount besides, with no other energy except that derived from its own engines. Therefore there can be no question but that a flying machine is now possible without the aid of a balloon in any form."

The termination of his experiments in this particular line he thus briefly relates: "I put everything in readiness, tied the machine up, fired the boiler and ran the engines, and with the throttle valves wide open the steam mounted to 350 pounds to the square inch. On liberating the machine it bounded forward with great velocity, lifted completely off the steel track, and when about 600 feet had been covered the lifting effect became so great that the Georgia Pine Upper track was broken and liberated the machine completely. I was then swinging in the air, but unfortunately one of the Georgia Pine planks was raised up and collided with one of the screws; the screw was smashed and the machine wrecked. And this was the end of my flying machine experiments."

The following review of Sir Hiram's aeronautical work we are permitted to extract from the long notice that appeared in the *Engineer* of December 1st, 1916:—

"The question of aviation had interested Maxim from his youth, since his father had endeavoured to devise a workable flying machine, but though he devoted a number of the later years of his life to the study of the subject, Sir Hiram Maxim never himself achieved successful flight. It is true that he relinquished his efforts before the perfection of the internal combustion engine, or he might have done more. He certainly did evolve a steam-engine plant, which developed more power for its weight than anyone had previously succeeded in doing, but even so the weight was too great. Moreover, the volume of water which it was necessary to carry would, even if his flying machine had been successful, have precluded it from making flights of any length.

The machine, however, embodied numerous ingenious arrangements and contrivances. It cannot be described as being a monoplane or a biplane, for such terms have come to be applied to specific forms of machines. There was, however, a large central plane having a surface of about 1400 square feet, and from this the machinery platform was suspended. There were, in addition, two curved planes disposed one on each side, and at about the level of the lower part of the machinery platform, these two planes being arranged symmetrically as regards one another. The arrangement, hence, partook of the nature of a biplane. In addition to the foregoing, there were fore-and-aft steering or elevating planes as well as side planes, the ends of which abutted on the side edges of the main plane. The numbers of these side planes could be varied, and, we believe, as many as a total of eight could be fixed. When the full plane area was in position there was a total wing surface of 5400 square feet. The total weight of the machine, including 600 lb. of water and 200 lb. of naphtha, was 8000 lb., so that there was 0.675 square foot of surface for each pound of weight.

"The machine was propelled by means of

two gigantic propellers, each weighing 135 lb., and each of them 17 ft. 10 in. in diameter, and with blades 5ft. 2 in. wide, the pitch being 16 ft. Each propeller was driven by a compound steam engine, poised about eight feet from the ground, and it was estimated that with 375 revolutions per minute, a speed of forty miles per hour would be attained. Maxim calculated that 150 horse-power was wasted in slip; that 133.33 horse-power would be expended in 'actual lift,' on the aeroplanes, and that 80.30 horse-power would be required to drive the machine, its frame, and wires through the air. This makes up a total of 363.63 horse-power, and that was the power which it was claimed the two engines together, developed on the brake. The weight of the engine is given as being 600 lb., so that the engines alone weighed only 1.65 lb. per brake horse-power. The boiler was an ingenious arrangement of copper tubes, which we described at the time as being something like both the Thornycroft and Yarrow boilers. It had 800 square feet of heating surface, and was fired by means of a specially-devised naphtha burner, in which the 'flame surface' was 30 square feet. For this burner the naphtha was first of all heated in what was called a 'gasolene boiler,' which would now be termed a vaporiser, and which was itself heated by naphtha. The heated naphtha gas was delivered to 7560 burner jets at a pressure of 50 lb. per square inch, this pressure being at the burner reduced to 1 lb. per square inch, the fall in pressure being made to do work in sucking in air to aid in the combustion. The boiler was also provided with a feed-water heater, and contained on an average 40 lb. of water. The pressure worked at was about 300 lb. per square inch or a little over. The combined weight of engines, boiler with water, and naphtha generator was 1900 lb., which represents 5.22 lb. per brake horse-power. The feed pumps weighed another 100 lb."

Of the many additional periodical publications regarding the aeronautical work of Sir Hiram, we select the following :—

Motor Car Journal, January 28th, 1911.

Harper's Magazine, for April 1911.

Hull Daily Mail, July 9th, 1912.

Engineer, 1891, p. 46 ; 1893 and 1894 ; 1900, August 24th, p. 192.

Engineering, for 1893, March 10th, pp. 288, 295 ; for 1894, August 3rd, p. 173 ; August 10th, pp. 195–6 ; August 24th, pp. 253, 256 ; for 1909, pp. 270–271.

North American Review, vol. clix., p. 344, on the development of aerial navigation.

AUTOMATIC GAS MACHINES

IT has been already stated that while at Fitchburg, Massachusetts, in the employ of his uncle, who had been given a contract to make some of the above-named machines, Sir Hiram had considerably improved upon their manufacture. He thus details the additional developments which he subsequently carried out :—

" While I was in the employ of Oliver P. Drake of Boston, I had noticed that the gas made by the machines then in use was very rich at the beginning of the evening and inclined to smoke, whilst, at the end of the evening, it was thin and blue. I asked Drake if it would not be a good plan to make a machine that would turn out gas of a uniform density. ' Yes,' said he, ' it would ; that is the trouble with our machines, but it is a chronic trouble, and there is absolutely no way to prevent it.' This set me thinking, and experimenting, fully realizing that carburetted air was much heavier than common air, and I made an apparatus to prove this.

"Later on, I went to New York, where I became a draughtsman at the Novelty Iron Works, and while there I made two very large gas machines. One of these was put up at Taylor's Hotel in Jersey City, and the other at the Americus Club in Connecticut, the latter organization being at that time headed by William M. Tweed. In these two machines I had a very light brass cylinder attached to one end of a scale beam, and a balance valve at the other, the whole being enclosed in a larger cylinder through which the gas had to pass. If it was too rich, it would buoy up the cylinder on the scale beam, and open the valve to admit pure air, but when the gas was of the right density the valve would be closed. These two machines worked perfectly, and were the first ever made that would produce carburetted air of a uniform density.

"I afterwards constructed two more machines on a totally different plan. I had found out that air expanded in being carburetted. I therefore made a machine with two pumps; two wet meter wheels on the same shaft. One pumped the air into the carburetter and the other pumped it out. If the gas expanded too much, or became too rich, a light valve was opened which allowed the air to pass from one pump to the other without going through the carburetter at all. In the next machine I converted all the gasolene into vapour under pressure, and made the escaping force of the vapour do all the work by pumping the air in.

"I made a great many of these machines. At one time I had a very large one in the Post Office at New York, another one in the hotel which was called 'The Woman's Home,' erected by A. T. Stewart. I had them also in all of A. T. Stewart's mills, and in many other places. The largest I ever made was for nine thousand burners. It was put up at Saratoga Springs, and it lighted the Grand Union as well as both the St James and the Windsor hotels."

OIL EXPERIMENTS

TRANSFORMING KEROSENE INTO MOTOR SPIRIT

DURING the last year of his life, Sir Hiram Maxim devoted his entire time exclusively to experiments for the purpose of discovering a ready process by which common kerosene could be changed into petrol, or rather, as he termed it, for the treatment of oils in order to obtain primarily through the "cracking" method a low-priced, effective liquid, suitable for use in motor vehicles of all descriptions.

"Cracking" is the process of distilling oils, composed of volatile elements so that their components may be separated by heat according to their respective volatilities. Bacon and Hamor state (*The American Petroleum Industry* 1916, vol. 2, pp. 558-559), that "the 'cracking' of heavy hydrocarbons by heat is to be regarded as simply an instance of the general rule that organic compounds are decomposed by heat. . . . Every refiner knows that certain crudes 'crack' more easily than others, which fact is to be accounted for by the presence of hydrocarbons of different constitution."

The process of "cracking" was made use of as far back as forty-four years ago by Sir Hiram Maxim whose original United States patent (No. 122,625, dated January 9th, 1872), embodies a third claim as follows: "The automatic heating of the retort or generator by the liquid that is condensed from the liquid hydrocarbon which is vaporized, substantially as set forth." The specification to this patent states that "the destructive distillation of the liquid hydrocarbon, and the production of a permanent gas will be gradual from the cooler to the hottest end, and there will consequently be but little residuum. The retort will not require to be as hot as usual, because the heavy oils are not all made into permanent gas, but only vaporized and subsequently condensed as well as burned in order to heat the retort. As aforesaid, this apparatus is automatic, and when the retort becomes too cool, the supply of combustible liquid is increased, and when the heat therefrom is too great, the liquid supplied will be lessened."

During the spring and summer of 1916, when the petrol question began assuming threatening proportions, and substitutes for the articles were in daily requisition, owing to the high prices then ruling, many attempts were daily reported by scientists here and elsewhere to find the means of obtaining a liberal supply of the much-needed fuel. Substitutes, such as came at different times on the market, found little favour, for none of them appeared to meet the trade requirements, and most investigators turned their attention to novel transformations of different products into petrol. Kerosene and other similar liquids were attacked on all sides, and one of the most pretentious series of plants erected for the purpose it is said, cost fully £70,000, but its treatment of heavy hydrocarbons was not successful, and the little progress attained in this particular quarter was so discouraging that all further attempts were abandoned and the plant disposed of.

As was stated at the above dates through the public prints, Sir Hiram Maxim had decided absolutely to leave all beaten tracks aside, and to initiate after a time a novel electrical treatment which he had long had in view, and for which elaborate drawings had at different times been prepared. In order to properly develop his plans he had rented the old Government Sorting Post Office at Herne Hill, than which a more suitable building could then not well have been found in London, and with the aid of his friend and associate, Mr Albert Vickers, as well as of the Vickers' very extensive and well-known manufacturing establishments in this city and elsewhere, he was enabled to promptly put together a most complete plant of all modern mechanical appliances.

Sir Hiram's experiments were, however, brought to an end by his death, November 24th, 1916, and it is not yet known whether there will be a continuation of his work in that particular line under the protection of either of the two provisional patents he had taken the precaution to secure. These two patents were :—

No. 8,477, June 15th, 1916. "Improvements in or relating to the production of light mineral oils."

No. 11,764, August 18th, 1916. "Improvements relating to the conversion of heavy hydrocarbons into lighter hydrocarbons."

VICKERS, SON & MAXIM, LTD.

HISTORY OF THE FIRM OF VICKERS

IT has already been stated that the above-named firm was organized July 20th, 1888, after the amalgamation of the Maxim Gun Company with the Nordenfelt Guns and Ammunition Company. Sir Hiram Maxim was directly connected thereafter with the Messrs Vickers, who controlled his inventions, and he did not cease active participation until his retirement during February 1911, on his seventy-first birthday.

Sir Hiram's resignation was publicly announced at the Annual Meeting of Vickers, Son & Maxim, Ltd., held at the River Don Works, Sheffield, March 28th, 1911, and presided over by Mr Albert Vickers. At this Meeting were also present the following directors: Lieutenant Sir A. Trevor Dawson, Sir Vincent Caillard, and Messrs Douglas Vickers, Vincent C. Vickers, William Beardmore, F. H. Baker and J. M'Kechnie. At the Extraordinary Meeting, which was held immediately after the Annual Meeting, it was moved and adopted that for brevity's sake, " the present name of this Company—Vickers, Son & Maxim, Ltd. —be discontinued, and that, in lieu thereof, the name of Vickers, Ltd. be adopted."

In the interviews subsequently reported, more especially by the London *Times* and the *Sheffield Daily Telegraph,* Sir Hiram stated that he was retiring from the Vickers' firm in order to return to his " old love," and to devote himself to the production of flying machines with Messrs Blériot and Grahame-White. This was in due time followed by the circulation of a Prospectus of a new firm called the " Grahame-White, Blériot & Maxim, Ltd." Capital £200,000.

At the time of the amalgamation with the Nordenfelt Guns and Ammunition Company by the Vickers' firm, and the latter's purchase of the Barrow-in-Furness Naval Construction Works, the following historical notes appeared in London *Engineering* (October 1st, 1897, pages 403-404). " The Vickers' firm was originally established over one hundred years ago by Mr George Naylor, the grandfather of two of the present managing directors (Mr Thomas E. Vickers and his brother, Mr Albert Vickers), and great grandfather of the other managing director Mr Douglas Vickers. . . . Mr Naylor commenced in partnership with Mr James Sanderson, under the name of Naylor and Sanderson, and they continued as merchants and manufacturers, with works in Sheffield until the year 1829, when the co-partnership was dissolved, and two new firms organized, both of which continued to play a prominent part in the industries of Sheffield. The one was Naylor, Hutchinson, (Edward) Vickers and Company, the other Sanderson Brothers and Company. . . . In 1856 Mr Edward Vickers relinquished the direct control of the manufacturing to his son, Mr Thomas E. Vickers, now the Chairman of the Company, and Mr Albert Vickers subsequently became a partner. . . . The co-partnerships, when the new works were started in 1864 at Brightside, on the outskirts of Sheffield, consisted of the late Edward Vickers and his sons, George Naylor Vickers, who died in 1889, Thomas Edward Vickers, the present Chairman, and Albert Vickers, both still managing directors, also Frederic Vickers who died in 1888. William Whitehead, who had long been an employee of the firm, was also a partner. . . . Edwards Reynolds, engineer, joined the establishment in 1863. . . . John Crossley, simultaneously with Mr Reynolds, was added to managing directors; he resigned his post in 1891, but remained on the Board, and his position was taken by Mr Douglas Vickers, son of the Chairman, who had first joined the establishment in 1879, became a manager in 1886, a director in 1889, and managing director in 1893. . . . The gun department of the Company is in charge of Lieutenant Arthur Trevor Dawson, late R.N., who held the appointment of Experimental Officer to the Royal Ordnance Factories at Woolwich, and who, prior to that, served on the staff of H.M.S. *Excellent*, the gunnery school at Portsmouth. . . ."

During the connection of Sir Hiram Maxim with the Vickers' firm, the latter was awarded three Grand Prizes and three Gold Medals for their exhibits at Paris Exposition, which not only included various forms of Maxim guns, but also some very fine pieces of high-power artillery, noticeably among which might be mentioned the 7-inch wire gun, which gives to its projectile a velocity of nearly 3000 feet per second.

From an article on "Munition Miracles," published by the *Daily Telegraph*, London, June 20th, 1918, the following is extracted:—

" A reference to field guns suggests at once the great armament firm of Vickers Limited. The branch of their works at Barrow, in the north-west area, is an industrial wonder and a national asset, the value of which can only be appreciated by a close inspection. On arrival at Barrow the interesting piece of information was imparted that the route to be traversed would be almost ten miles long.

" Vickers Limited are counted among the most versatile engineering firms of the world. They can produce a battleship complete, and in the days of peace their efforts were far from being confined to armaments. It is impossible to describe in detail all that is occurring at Barrow, but with employees, men and women, concentrating their efforts in meeting the requirements of war time, it can be imagined that the American visitor who ventured the opinion that there was ' something doing ' was quite correct. One of the most stimulating departments is that devoted to shipbuilding. War-time activity prevails, and the noise of hammering and the quick, staccato sounds of the pneumatic riveter are as acceptable to the ear as music. Everybody is busy. The firm is equipped for the production of battleships, cruisers, cargo vessels, passenger liners, submarines, floating docks, and other craft. Large totals show their activity in shell production, and an interesting example of the way in which female labour is utilized is afforded by young women controlling moving cranes which move maximum weights in the minimum of time. The submarine dock provides another interesting scene. The pioneer work of Vickers Limited, in the construction of submarines is well known. Whether it be the submarine shop, the smithy, the foundry, the shell shops, or marine engine shops, the story is the same —war pressure is supplying the keynote for activity, and after visiting the airship shed, a feeling of gratitude arises for the existence of an institution like that of Vickers Limited. There are other great munition resources in the north-west area, but sufficient has been written for one article to indicate the way in which Lancashire has harnessed itself to the chariot of war."

APPENDIX I

NOTES

Note 1

Abel, Sir Frederick Augustus (1827–1902) was a very leading authority on explosives of all descriptions, and, in addition to improving the manufacture of gun-cotton, was the inventor of cordite, co-jointly with Sir James Dewar, of the Royal Institution. He became Professor of Chemistry at the Royal Military Academy, Woolwich, 1851–1855, was chemist to the War Department, 1854–1858, and wrote many notable scientific works, amongst which may be specially mentioned *Gun-Cotton*, 1866; *The Modern History of Gunpowder*, 1866, and three separate publications on *Explosives*, 1872, 1875, 1884.

Note 2

Acetone-pyro-acetic spirit—dimethyl ketone, a very inflammable liquid related to acetic acid, but containing less oxygen. See Cordite.

Note 3

Alverstone, Lord, formerly Sir Richard Everard Webster (1842–1915), succeeded Sir Nathaniel Lindley as Master of the Rolls, and succeeded Lord Russell of Killowen as Lord Chief Justice of England. This was after one of the most brilliant records at the Bar, especially in patent cases, and after very distinguished service as Attorney-General during three separate terms, 1885–1886, 1886–1892, 1895–1900.

Note 4

Armstrong, Sir William George, Bart. (1810–1900), founder of the Elswick Manufacturing Works, which latter is well known for its ordnance production. Its first guns appeared in 1855, and they were at once adopted by the British Government, Armstrong himself being appointed Engineer of Rifled Ordnance. He is the author of an interesting work entitled *Electric Movement in Air and Water*, which came out in 1897.

Note 5

Ayrton, Mrs Hertha, native of Portsea, took honours in mathematics at Girton College, Cambridge, and became the wife of Prof. W. E. Ayrton, F.R.S., a very distinguished English scientist, with whom she achieved much progress in electrical channels. Many papers have been read by her before several British Association Meetings, as well as before the Paris International Congress, the Royal Society, and the Institution of Electrical Engineers, of which latter she has thus far been the only lady member.

Note 6

Ballistite. A dark coloured smokeless powder, formed in equal parts of soluble cellulose nitrates and of nitroglycerine. Very similar to cordite.

NOTE 7

Boys, Professor Charles A. Vernon, F.R.S. (n.d.), was Assistant Professor of Physics at the Normal School of Science, served on Juries at the Paris Expositions for 1889 and 1900, as well as at the Saint Louis Exhibition of 1904, and is the author of many papers that have appeared in the scientific publications of his time.

NOTE 8

Bramwell, Sir Frederick (1818–1903), English scientist who became President of the Institution of Civil Engineers in 1874, and was made President of the British Association during 1888.

NOTE 9

Cambridge, George William Frederick Charles, Duke of (1819–1904), led the English troops at the Alma and at Inkermann, became Field-Marshal, and was appointed Commander-in-Chief during the year 1887, being succeeded in the latter office by Lord Wolseley.

NOTE 10

Clarke, Sir Andrew (1824–1902), appointed Director of Works for the Navy in 1864, made great improvements in the Arsenals at Chatham and elsewhere, as well as in the defences of Cork and Malta. He was appointed Inspector General of Fortifications, 1882–1886.

NOTE 11

Cloete, Willian Brodrick (*b.* 1851), at one time director of the firm of Vickers, Son & Maxim, Ltd., was her late Majesty's High Commissioner for Natal, and, as we have seen in the chapter treating of Aerial Torpedoes, formed part of the syndicate which was working on the Maxim automatic gun. The other members of this syndicate were Messrs Albert and Douglas Vickers, Robert Symon and Bryce Douglas.

Note 12

Cordite. A smokeless powder composed of nitro-glycerine, gun-cotton, and mineral jelly, to which mixture acetone is added. It is so called from its cord or string-like appearance before it is dried and cut into lengths. It was introduced in 1889, and it is said that a velocity of 2669 feet has been obtained with a charge of 19½ pounds of cordite from a quick-firing six-inch gun.

Note 13

Crookes, Sir William (1832–1919), Past President of the Chemical Society, the British Association, the Institution of Electrical Engineers, the Royal Society, etc., made many important discoveries, and has written extensively on much that Sir Hiram Maxim has introduced to us throughout the present work. Sir William Crookes is especially mentioned herein as shown in the Index.

Note 14

Dewar, Sir James (1842–), already mentioned in the Note concerning Sir F. A. Abel, has long been the Fullerian Professor of Chemistry at the Royal Institution, and was President of the British Association, also President of the Chemical Society, and Vice-President of the Royal and other Societies. He numbers among his numerous inventions the form of smokeless powder used by the British Government, was not long since a member of the leading Explosives Committee, and has received the first English award of the Lavoisier gold medal, as well as numerous other distinctions from various countries.

NOTE 15

Draper, John William (1811–1882), distinguished scientist who was actively engaged with Professor Samuel F. B. Morse in introducing the electro-magnetic telegraph throughout the United States, and who became the first President of the American Chemical Society.

NOTE 16

Edison, Thomas Alva (1847–), who, as will be seen in the Index, has been several times mentioned herein, introduced duplex telegraphy, carbon filaments for incandescent electric lamps, the stock-printing telegraph, microtasimeter, phonograph, carbon transmitter, cinematograph, etc. etc.

NOTE 17

Fuze—fuse—is name given to a tube, cord, ribbon, casing, impregnated with combustible matter, or a kind of detonator, by which shells, cannon, mines, etc., are ignited and exploded. A fuze can be cut or otherwise shortened in order to burn for any required period of time. The electric fuze, invented by Sir F. A. Abel, was composed of subsulphide also subphosphide of copper and potassium chlorate. The delayed (retarded) action fuze is mentioned herein as per Index.

NOTE 18

Kelvin, Lord (William Thomson, Bart.) (1824–1907), whose electrical and magnetical researches were probably more extended than those of any scientist, was President of the Royal Society, and became head of numerous other leading scientific organizations, throughout England more particularly. For a full account of his writings and inventions consult Andrew Gray, *Lord Kelvin*, 1908, and S. P. Thompson, *Life of Lord Kelvin*, 1910.

NOTE 19

Langley, Samuel Pierpont (1834–1906), American physicist, who became Director of the Allegheny Observatory in 1867, and Secretary of the Smithsonian Institution at Washington ten years later, made, during the year 1896, the first known successful aeroplane flight while experimenting on the Potomac river.

NOTE 20

Lyddite, named after the town of Lydd, in Kent, where this very high explosive was first introduced. It is composed chiefly of picric acid, and is practically the English name for the French Melinite. The original English lyddite was modified with both di-nitro benzole and vaseline.

Note 21

Majendie, Colonel Sir Vivian Dering, C.B., 1881, K.C.B. 1895, Col. R.A., retired 1881, died 1898. He served in both the Crimean and the Indian Mutiny campaigns, was appointed H.M. Chief Inspector of Explosives, 1871, and became editor of the *Official Guide to the Explosive Act*. He was the author of *Ammunition*, and of very numerous technical papers communicated to different scientific bodies.

Note 22

Maximite—Maxim-ite—a smokeless gunpowder, composed of gun-cotton, nitro-glycerine and castor oil, which is said to have proved very effective, especially when employed in armour-piercing shells.

Note 23

Melinite, already mentioned at the Lyddite entry, is a yellow-coloured composition, consisting chiefly of picric acid, gun-cotton, and gum arabic, dissolved in ether. Its explosive force is said to be more than ten times that of ordinary gunpowder. See *Explosives*.

Note 24

Moulton, the Right Honourable Lord, P.C., K.C.B., G.B.E., F.R.S., etc., Commander of the Legion of Honour, Commander of the Order of Leopold of Belgium, Grand Cordon of the Order of the White Eagle of Russia, etc. etc. (formerly John Fletcher Moulton, K.C., M.P.), has been Director-General of Explosives Supply since 1914. After a brilliant career at Cambridge, where he was Senior Wrangler and first Smith's Prizeman, he was called to the Bar in 1874, became Q.C. in 1885. Treasurer of the Middle Temple 1910. Lord Justice of Appeal 1906. Lord of Appeal since 1912. Is a Fellow and Member of the University of London; was the the first Chairman of the Medical Research Committee under the National Insurance Act.

NOTE 25

Nobel, Alfred Bernhard (1833–1896), Swedish chemist, who experimented for a long period on explosives generally, and gave much attention to the manufacture of nitroglycerine. He obtained a patent for dynamite in 1867, and also discovered ballistite, a smokeless powder, which was the precursor of cordite, and led to his unsuccessful law suits against the English Government during 1894–1895.

NOTE 26

Noble, Sir Andrew (1832–1915), was, in turn, Chairman of Sir W. G. Armstrong, Whitworth & Company, Ltd., Secretary to Committee on Rifled Cannon, Secretary to Committee on Plates and Guns, Assistant Inspector of Artillery, and Member of both the Ordnance Select Committee and of the first Committee on Explosives. He wrote many very important works upon explosives, upon the science of gunnery, etc.

NOTE 27

Obturator—obturating gas check—*cartouche obturatrice*—a device which "obturates" (*i.e.* closes up, makes stubburn, hardens) or seals the breech at the moment of explosion. The obturator was first properly introduced by Colonel De Bange of the French Artillery service, and is intended to check or prevent the escape of gas at the breech of a cannon. The most prominent of such devices, besides the De Bange, are known as the Freire obturator, the obturating primer, the Broadwell ring, and the Armstrong gas check.

NOTE 28

Palmer, Sir Charles Mark (1822–1907), British shipbuilder, whose firm produced warships and other vessels, and whose system of rolling armour plates was almost universally adopted. During 1865, his business was transferred to the Palmer Shipbuilding and Iron Company, Limited.

NOTE 29

Parrott, Robert Parker (1804–1877), Superintendent of the West Point Cannon Foundry, perfected a system of rifled guns and of projectiles—which gave them greater endurance—and which was almost as widely employed throughout the world as was the system of Benjamin B. Hotchkiss. Parrott's guns were constructed on the plan laid out by Thomas J. Rodman, and the records show that one of his rifled 30-pounders, employed against Charleston, was fired 4606 times before bursting.

NOTE 30

Preece, Sir William Henry, K.C.B. (1834–1913), was President of the Institution of Civil Engineers, after having, in turn, received the appointments of Superintendent of the Electric and International Telegraph Company and of Engineer to the Channel Islands Telegraph Company. From the last-named he was transferred to the General Post Office, as Engineer-in-Chief, and while thus employed wrote many important scientific papers, which were communicated to the leading societies of his day.

NOTE 31

Rodman, Thomas Jefferson (1815–1871), who was long connected with the Ordnance Department at West Point, was the inventor of a valuable method of gun-casting about a hollow core through which a stream of cold water is kept running. This system was successfully applied upon a large scale during the American Civil War, and two of his 20-inch smooth bore guns have since been placed at the entrances to the Panama Canal.

NOTE 32

Salisbury, Robert Arthur Talbot Gascoyne-Cecil, third Marquis of (1830–1903). The fourth Marquis, James Edward Hubert Gascoyne-Cecil (1861–), is a very distinguished statesman and author. For family, consult Puling, Ellis, Aiken, etc.

NOTE 33

Sawyer, William E., cannot be identified satisfactorily, but Sawyer, William Silvanus, who was born in 1822, should be named amongst those who have distinguished themselves in the manufacture of Ordnance. He invented, during 1883, many improvements in rifled gun projectiles, so constructed as to prevent the side passages of gas—"windage"—and he likewise so devised a percussion cap, as to insure the shell explosion on impact. Amongst his many other inventions, should be especially mentioned the 42-pounder rifled columbiads, so very successfully employed at Fort Wood and at Newport News, 1862–1864.

NOTE 34

Smithsonian Institution was established at Washington, in the District of Columbia, "for the increase and the diffusion of knowledge among men," under the will of James Smithson.

NOTE 35

Turpin, Eugène, admittedly a very ingenious inventor, was the first to discover the possibility of detonating picric acid by itself. This he did in 1886 (Guttmann, Oscar, *Manufacture of Explosives*, 1895, p. 159, vol. II.). He was the patentee of the panclastiles (*Explosives and their Power*, translated from the French by M. Berthelot, 1892, pp. 397–398), and at pages 138–139, 336, of *Les Explosives Modernes*, by Paul F. Chalon, Paris, 1911, will be found particulars regarding the many inventions he secured during 1885–1888. Consult, likewise, *Matières Explosives*, par Léon Gody Namur, 1907, pp. 266, 270, 641, and *Explosives*, by Arthur Marshall, London, 1917, pp. 49–50.

NOTE 36

Von Lenk, Baron, Austrian chemist of note, whose investigations, patents, and processes are detailed at pp.

210–212 of *Lectures on Explosives*, by Willoughby Walke, New York, 1897. For a further account of Von Lenk's work, consult Arthur Marshall, *Explosives*, 1917, pp. 39, 169, 182.

NOTE 37

Wallace, David (1799–1859), was the one who, as member of the United States Congress, gave the casting vote in favour of a liberal appropriation for the development of Samuel F. B. Morse's magnetic telegraph.

NOTE 38

Wallace, William. Born in Manchester, England, March 16th, 1825, went to America with his parents in 1832, and settled permanently during 1841 at Birmingham, Connecticut, where he established the well-known manufacturing firm of Wallace & Sons. His several extraordinary contributions, to electricity especially, have been well reviewed by the able scientist, William J. Hammer, in the 1893 *Electrical Engineer* of New York City.

NOTE 39

Webster, Sir Richard Edward, see Alverstone, Lord.

NOTE 40

Whitehead torpedo. The details of the construction and introduction of this important arm of the American Service are to be found most readily in the different encyclopaedias, notably in the *International*, vol. xix., pp. 359–361.

Note 41

Wolseley, Sir Garnet Joseph, Lord (1833–1913) after very distinguished service in the Crimea, China, Zululand, and elsewhere, became Commander-in-Chief of the troops in Ireland, 1894, and was appointed Commander-in-Chief of the British Army the year following, only resigning in favour of Lord Roberts during 1900.

Note 42

Zalinski, Edmund Louis Gray (*b.* Dec. 13, 1849), American artillerist, native of Prussian Poland, was Professor of Military Science at the Massachusetts Institute of Technology, and made numerous valuable improvements in ordnance generally. His most important invention was that of the pneumatic dynamite torpedo gun, but his electrical fuze, his telescopic sights for artillery, and his system of range-finding for artillery firing, likewise attracted much attention throughout the scientific world.

APPENDIX II

LIST OF AMERICAN AND BRITISH PATENTS

GRANTED TO

HIRAM STEVENS MAXIM

AMERICAN PATENTS

1866	August	21	57,354	Improvement in irons for curling hair
1867	November	26	71,400	Improvement in steam gas generators
1868	June	2	78,465	Improved gas machine
1868	September	8	81,922	Improvement in carburettors
1869	May	4	89,588	Improved apparatus for making illuminating gas from gasoline
1869	October	5	95,498	Improvement in locomotive head-lights
1870	February	15	99,927	Improved apparatus for generating gas for head-lights
1870	May	3	3,950	Re-issue of patent No. 71,400
1871	October	24	120,302	Improvement in gas-machines
1871	December	26	122,272	Improvement in steam-traps
1872	January	9	122,625	Improvement in gas apparatus
1872	June	11	127,907	Improvement in liquid meters
1873	January	21	5,247	Re-issue of patent No. 81,922
1873	July	22	141,062	Improvement in fire extinguishers
1873	July	22	141,063	Improvement in steam-traps
1874	May	5	150,478	Improvement in feed-water heaters
1874	May	26	151,235	Improvement in steam and vacuum pumps
1874	December	22	158,105	Improvement in automatic pumping engines

1875 February	23	160,215	Improvement in feed-water heaters
1875 February	23	160,216	Improvement in apparatus for manufacturing illuminating gas from liquid hydrocarbons
1875 April	6	161,621	Improvement in liquid meters
1875 July	20	165,744	Improvement in engine governors
1876 May	23	177,733	Improvement in liquid meters
1878 June	11	204,747	Improvement in feed-water regulators
1878 September	24	208,252	Improvement in electric lamps
1878 September	24	208,253	Improvement in regulators for electric lamps
1879 March	4	212,857	Improvement in carburettors
1880 June	8	228,543	Dynamo-electric machine
1880 June	8	228,544	Dynamo-electric machine
1880 June	8	228,545	Commutator for magneto-electrical machines
1880 June	8	228,546	Brush for magneto-electrical machines
1880 June	8	228,547	Gas apparatus
1880 July	20	230,309	Process of manufacturing carbon conductors
1880 July	20	230,310	Electric lamp
1880 August	10	230,953	Electric lamp
1880 August	10	230,954	Process of removing air from globes of electric lamps
1880 November	2	233,942	Dynamo-electric machine
1880 November	23	234,835	Electric lamp
1881 February	1	237,108	Electric lamp
1881 March	29	239,394	Process of and apparatus for manufacturing phosphoric anhydride
1881 July	12	244,277	Electric lamp
1881 July	19	244,501	Carbon holder for electric lamps
1881 August	16	245,736	Gas machine
1881 September	13	247,083	Process of manufacturing carbons
1881 September	13	247,084	Incandescent electric lamp
1881 September	13	247,085	Process of manufacturing carbon conductors
1881 September	13	247,086	Chandelier for electric lamps
1881 September	20	247,380	Electric lamp
1881 September	27	247,569	Art of and apparatus for cutting or dividing stone
1881 November	29	250,273	Method of and apparatus for demagnetizing watches
1881 December	6	250,561	Gas machine
1881 December	27	251,614	Apparatus for extinguishing fires
1882 January	17	252,391	Electric lamp
1882 January	17	252,392	Electric lamp
1882 January	24	252,840	Electric lamp
1882 February	21	254,032	Electric lamp

1882	March	7	254,672	Carbon for electric lamps
1882	March	21	255,304	Electric lamp
1882	March	21	255,305	Electric lamp
1882	March	21	255,306	Electrical meter
1882	March	21	255,307	Electrical meter
1882	March	21	255,308	Electrical meter
1882	March	21	255,310	Speed regulator for dynamo-electric machines
1882	March	21	255,311	Regulator for dynamo-electric machines
1882	March	21	255,312	Electrical engineering
1882	April	25	256,910	System of electrical generation and distribution
1882	May	2	10,101	Re-issue of patent No. 99,927
1882	July	25	261,741	Mode of making electric lamps and carbons for the same
1882	September	5	264,042	Apparatus for treating carbon conductors
1882	September	26	264,951	Apparatus for making incandescent lamps of equal resistance
1882	September	26	264,952	Method of and apparatus for "forming" storage batteries
1882	December	26	269,805	Regulator for dynamo-electric machines
1883	March	13	273,750	Gas engine
1883	April	3	275,060	Gas machine
1883	May	15	277,846	Process of manufacturing carbons for incandescent lamps
1883	June	19	279,657	Gas engine
1883	August	21	283,629	Electric lamp (assigned to U.S. Electric Lighting Company of New York)
1884	January	1	291,065	Gas motor
1884	February	5	293,185	Hot air or gas engine
1884	February	19	293,762	Gas motor
1884	March	25	295,784	Gas engine
1884	April	8	296,340	Gas engine
1884	April	8	296,341	Electrical igniting device for gas engines
1884	April	22	297,278	Mechanism for operating gun-locks by recoil
1884	July	22	302,271	Gas motor
1885	May	5	317,161	Machine gun (assigned to Albert Vickers and Robert R. Symon)
1885	May	5	317,152	Magazine fire-arm (assigned to Albert Vickers and Robert R. Symon)
1885	June	9	319,595	Magazine fire-arm
1885	June	9	319,596	Machine gun
1885	July	7	321,513	Machine gun (assigned to Albert Vickers and Robert R. Symon)

1885 July	7	321,514	Machine gun (assigned to Albert Vickers and Robert R. Symon)
1885 November	3	329,471	Support for machine guns
1886 August	24	347,945	Recoil mechanism for guns
1887 August	9	367,825	Machine gun
1887 November	22	373,466	Manufacture of guns
1888 January	24	376,990	Manufacture of guns
1888 August	14	387,651	Method of making cartridge shells
1889 January	8	395,791	Machine gun
1889 April	16	401,708	Riveting machine
1889 May	7	402,684	Magnetic separator
1889 June	11	405,170	Manufacture of filaments for electric lamps (assigned to U.S. Electric Lighting Company of New York)
1889 June	11	405,239	Apparatus for the manufacture of filaments for incandescent lamps
1889 July	23	407,487	Apparatus for adjusting, pointing, or training cannon
1890 March	25	424,119	Gun
1890 June	17	430,136	Apparatus for working ordnance
1890 June	17	430,210	Automatic gun
1890 June	17	430,211	Automatic machine gun
1890 June	17	430,212	Manufacture of explosives
1890 June	17	430,213	Carburettor
1890 June	17	430,214	Recoil-check for ordnance
1890 June	17	430,215	Recovering solvents from explosives
1890 August	12	434,049	Explosive compound
1890 September	23	436,898	Manufacture of explosives
1890 September	23	436,899	Automatic gun
1890 October	28	439,248	Machine gun
1890 December	23	443,101	Projectile
1891 February	17	446,532	Process of and apparatus for hardening ordnance
1891 March	3	447,524	Automatic gun
1891 March	3	447,525	Automatic gun
1891 March	10	447,836	Automatic gun
1891 March	10	447,837	Automatic machine gun
1891 April	7	449,687	Process of and apparatus for making explosives

BRITISH PATENTS

1883 June	26	3,178	Mechanism for facilitating the action of magazine rifles and other fire-arms
1883 July	16	3,493	Machine or battery guns and cartridges for the same and other fire-arms

1884	January	3	606	Improvements in and relating to machine guns and other fire-arms
1884	February	23	3,844	Improvements in and relating to machine or battery guns
1884	May	21	8,035	Improvements in and relating to apparatus for cooking, digesting, or similar purposes
1884	May	23	8,153	Improvements in and relating to breech-loading and other guns
1884	May	23	9,407	Improved feed apparatus for machine or battery guns or other fire-arms
1884	May	26	8,242	Improvements in magazine or repeating rifles and other guns
1884	May	26	11,685	Improvements in cartridges
1884	October	2	13,113	Improvements in and relating to machine and other guns
1884	October	17	13,762	An improved method of and apparatus for adjusting, pointing or training cannon. (In names of Robert Rintoul Simon and Hiram S. Maxim)
1885	January	8	288	Improvements in the manufacture of guns
1885	January	8	3,680[1]	Improvements in machines for coiling and soldering metal ribbon or wire, chiefly designed for use in the manufacture of guns
1885	January	14	552	Improvements relating to the manufacture of gunpowder and to cartridges or charges containing or formed of the same
1885	January	29	1,307	Improvements in and relating to machine or battery guns and other fire-arms
1885	February	14	2,090	Improvements in cartridges. Claim No. 5 covers "*the employment of paraffin wax*")
1885	March	7	3,019	Improvements in and relating to apparatus for working ordnance
1885	April	27	5,199	Improvements relating to means for preventing the fouling or jamming of cartridges in machine or in battery guns

[1] This 3680 is entered in the Official 1885 Volumes (between Nos. 3678 and 3683) under date January 8th, 1885, although the Provisional is dated March 21st, 1885 and the Complete, October 8th, 1885.

1885 May	30	6,591	Improvements in guns and explosive projectiles therefor, chiefly designed for destroying ships. (*Aerial torpedoes*)
1885 June	8	6,926	Improvements relating to the manufacture of explosive compounds
1885 July	8	8,281	Improvements in machine and other guns
1885 November	17	14,047	Improvements in machine and other guns and pistols, and in projectiles therefor
1886 February	22	2,581	Improvements in and relating to machine and other guns
1886 April	5	4,751	Improvements relating to the application and utilization of magnetism or electro-magnetism for the separation of metals and for other purposes, and to apparatus therefor
1886 June	1	7,354	Improvements in and relating to automatic and other guns or fire-arms
1886 August	20	10,686	Improvements in eyeletting and rivetting machines
1886 October	2	12,561	Improvements in the manufacture of cartridges and explosive projectiles
1886 October	13	13,083	Improvements relating to machine guns and other fire-arms and to apparatus to be used in the manufacture thereof
1886 October	22	13,534	Improvements relating to cartridges, projectiles and fuzes, to means for regulating the action of such fuzes, and to apparatus for use in the manufacture of the said projectiles
1886 December	1	15,734	Improvements in and relating to machine and other guns
1886 December	18	16,672	Improvements in and relating to locomotive or manœuvred torpedoes
1887 February	19	2,628	Improvements relating to the manufacture and treatment of dynamite, blasting gelatine and similar explosive compounds and to apparatus therefor
1887 March	22	4,320	Improvements relating to the manufacture of guns

1887 March 30	4,778	Improvements in and relating to quick-firing guns and other fire-arms
1887 October 14	13,975	Improvements relating to the pointing or aiming of fire-arms and to apparatus therefor
1887 November 19	15,952	Improvements in the manufacture of projectiles or shells and other forged metal articles and in apparatus therefor
1887 December 8	16,877	Intermittent water discharge applicable to the washing out of drains, water-closets, and to similar purposes
1887 December 15	17,252	Improvements relating to guns, chiefly designed for use with projectiles containing dynamite and similar explosive materials
1887 December 15	17,253	Improvements in the treatment of rifle barrels to prevent them from becoming crooked while firing
1888 June 8	8,428	Improvements in and relating to quick-firing guns and other fire-arms
1888 August 30	72,518	Improvements in apparatus for naphthalizing or carburetting illuminating and other gas
1888 September 20	13,624	Improvements relating to the tempering and toughening of ordnance and to apparatus therefor
1888 November 8	16,213	Improvements relating to the manufacture of explosives and to apparatus therefor
1888 December 20	18,663	Improvements relating to the manufacture of explosives and to apparatus therefor
1889 January 14	703	Improvements in and relating to apparatus for carburetting gas
1889 February 12	2,508	Improvements in and relating to apparatus for carburetting gas
1889 March 14	4,477	Improvements in the manufacture of explosive compounds
1889 June 25	10,359	Improvements relating to steam engines and generators and to apparatus for use in connection therewith
1889 October 25	16,883	Improvements in and relating to aeronautical apparatus

1890	January	14	680	Improvements relating to armour-piercing and other projectiles or shells
1890	February	5	1,951	Improvements relating to machinery or apparatus for the manufacture of explosives and for similar purposes
1890	February	17	2,559	Improvements relating to the carburetting or enrichment of coal and other gas and to apparatus therefor. (In names of Hiram S. Maxim and George Stanley Sedgwick)
1890	March	21	4,471	Improvements relating to the pointing, training or laying of guns, and to apparatus therefor
1890	April	3	5,209	Improvements relating to the manufacture of explosives and to apparatus therefor
1890	April	29	6,585	Improvements relating to automatic guns
1890	April	29	6,591	Improvements relating to automatic guns
1890	September	30	15,483	Improvements relating to the manufacture of explosives and to apparatus therefor
1890	December	5	19,886	An improved method and apparatus for preventing or diminishing the rolling and pitching of ships or vessels
1891	November	6	19,228	Improvements in and relating to aeronautic apparatus
1891	December	31	22,859	Improvements in and relating to breech-loading fire-arms
1892	January	26	1,563	Improvements in or relating to ships or vessels for increasing the speed thereof
1892	April	13	7,156	Improvements in automatic guns. (In names of H. S. Maxim and Louis Silverman)
1892	July	6	12,508	An apparatus for indicating the flow of fluid, chiefly designed for use as an indicating feed-water check-valve
1892	October	26	19,254	Improvements in and relating to steam generators
1892	December	5	22,267	Improvements in wheels for railway and tramway vehicles and engines
1893	March	4	4,780	Improvements in and relating to cartridges

1893 June 2	10,852	Improvements in aerial machines
1893 October 31	20,591	Improvements in and relating to breech-loading ordnance. (In names of H. S. Maxim and Louis Silverman)
1894 February 24	4,019	Improvements in cartridges
1894 May 8	9,123	Improvements in and relating to electric railways
1894 August 25	16,260	Improvements in and relating to automatic and machine guns and their stands or supports. (In names of H. S. Maxim and Louis Silverman)
1894 September 21	17,994	Improvements relating to smokeless explosives
1894 October 27	20,627	Improvements in and relating to automatic guns
1895 January 17	1,166	Improvements relating to quick-firing ordnance, and to mountings and turrets, and to methods of and means for working the same
1895 March 20	5,864	Improvements in or relating to automatic guns
1895 March 26	6,274	Improvements in steam engines
1895 May 30	10,761	Improvements in automatic guns
1895 June 29	12,611	Quick-firing ordnance. (Provisional patent only)
1895 July 26	14,283	Improvements in carriages or mountings for automatic or other light guns. (In names of H. S. Maxim and Louis Silverman)
1895 November 27	22,708	Improvements in the manufacture of pipes or tubes and in apparatus therefor. (In names of H. S. Maxim and Hudson Maxim)
1895 November 28	22,812	An improved process of extracting gold from refractory auriferous ores
1895 December 7	23,495	Guns (Provisional patent only)
1895 December 10	23,689	Improvements in or relating to automatic guns
1896 January 18	1,335	Guns (Provisional patent only).
1896 February 26	4,342	Guns (Provisional patent only)
1896 March 31	7,045	Improvements in automatic machine guns
1896 April 8	7,468	Improvements in automatic guns
1896 April 16	8,076	Improvements relating to automatic guns
1896 May 5	9,526	Improvements in and relating to oil or gas engines

1896 May	5	9,579	Improvements in pneumatic tyres
1896 May	6	9,666	Improvements in pneumatic tyres
1896 May	7	9,757	Improvements in the manufacture of inflatable or pneumatic tyres and in apparatus therefor
1896 May	22	11,214	Improvements in pneumatic tyres
1896 October	24	23,715	Improvements in and relating to the crank shafts of velocipedes
1896 December	8	28,093	Improvements relating to projectiles for ordnance
1896 December	28	29,836	Improvements in automatic and similar breech-loading fire-arms
1897 January	4	207	Improvements in the firing mechanism of automatic guns
1897 April	28	10,620	Improvements in aerial or flying machines
1897 May	5	11,257	Improvements in wheels for vehicles
1897 August	25	19,649	Improvements in detachable heel-protectors for boots and shoes
1897 November	11	26,343	Improved methods of and apparatus for manufacturing filaments for electric lamps
1898 January	21	1,720	Improvements relating to projectiles for ordnance
1898 February	25	4,738	An improved method of and apparatus for obtaining a high vacuum
1898 August	9	17,177	Improvements in mercurial air-pumps
1898 December	15	26,527	Improvements in regulators for electric car motors
1899 April	7	7,362	Improvements in and relating to projectiles for ordnance
1899 May	12	10,071	Improvements in the manufacture of explosives
1899 May	30	11,288	Improvements in and connected with motor-driven velocipedes and other light vehicles
1899 July	17	14,717	Improvements in projectiles
1899 August	8	16,157	Improvements in projectiles for ordnance
1899 October	13	20,587	Improvements relating to electric railway conduit systems
1900 February	22	3,529	Improvement relating to the manufacture of perforated explosive or other plastic material and to apparatus therefor
1901 February	13	3,129	Improvements relating to the treatment of coffee and the production of coffee substitutes
1901 April	24	8,463	Improvements relating to projectiles

1901 August	20	16,694	Improvements relating to fuzes for armour-piercing projectiles
1902 August	29	19,017	Improvements in fuzes for explosive projectiles
1902 December	22	28,246	Improvements relating to the shafts of screw propellers
1903 July	16	15,748	Improvements relating to rotating cars or roundabouts for public recreation or experimental purposes and to apparatus for actuating the same
1904 February	8	3,120	Improvements in and relating to roundabouts
1904 June	14	13,464	Improvements relating to roundabouts and similar contrivances for public recreation
1904 October	10	21,771	An improved device for producing illusionary effects
1906 April	9	8,520	Improvements in fuel-feeding devices for internal combustion engines
1906 April	9	8,537	Improvements in wheels for vehicles
1906 September	25	21,256	Improvements in devices for advertising purposes
1906 October	15	22,788	Improvements in and relating to apparatus for vacuum cleaning purposes
1907 June	19	14,198	Improvements in or relating to apparatus for use in the extraction of dust
1908 March	25	6,680	An improved device for lessening the sound of discharge of guns
1908 April	30	2,482	Improvements in devices for advertising purposes
1908 September	23	20,010	Improvements in the determination of wind velocity
1908 September	23	20,038	Improvements in and relating to flying machines
1908 November	18	24,790	Improvements in and relating to carburettors
1909 January	9	602	Aerial navigation (Provisional patent only)
1909 January	9	608	Improvements in or relating to carburettors for internal combustion engines
1909 April	21	9,512	Flying machines (Provisional patent only)
1909 May	24	4,473	Aerial navigation (Provisional patent only)
1909 August	20	19,172	An improved inhaler

1910 March	8	5,843	Aeroplanes (Provisional patent only)
1911 March	28	7,774	Improvements in and relating to bombs for use in connection with aeroplanes or flying machines
1911 April	1	8,220	Improvements in or relating to bombs for use with aeroplanes and other flying machines
1911 October	2	21,722	Improvements in or relating to bombs for use with aeroplanes and other flying machines
1914 March	20	7,102	Improvements in or relating to high-angle guns (Provisional patent only)
1914 June	25	15,251	Improvements in or relating to the preparation of coffee or coffee extract (Provisional patent only)
1914 November	25	23,068	Improvements in or relating to cooking apparatus (Provisional patent only)
1915 March	2	3,370	Improvements in or relating to fire-arms. (Abandoned, after the complete specification was filed)
1915 May	21	7,669	Improvements in or relating to apparatus for dissipating noxious gases (Provisional patent only)
1916 January	10	421	Improvements in or relating to silencing devices for guns (Provisional patent only)
1916 February	10	2,021	Improvements in or relating to silencing devices for guns (Provisional patent only)
1916 June	15	8,477	Improvements in or relating to the production of light mineral oils. (Provisional patent only)
1916 August	18	11,764	Improvements relating to the conversion of heavy hydrocarbons into lighter hydrocarbons (Provisional patent only)

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